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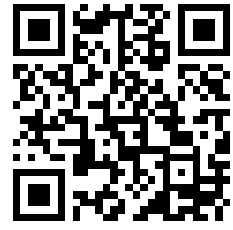

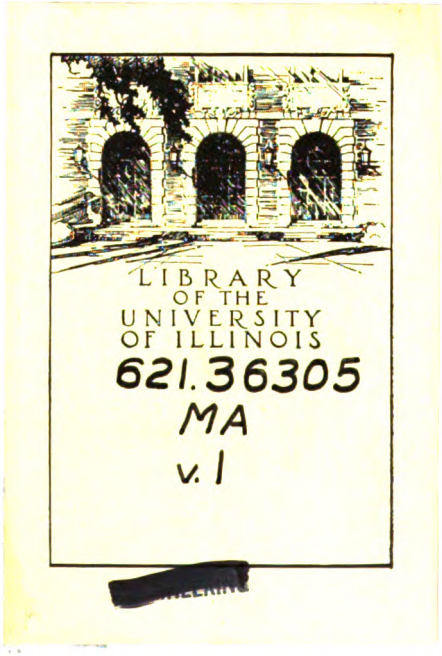
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THE MARCONI REVIEW

October, 1928

CONTENTS

FOREWORD. BY SENATORE G. MARCONI, G.C.V.O., LL.D., D.Sc. - - - PAGE 1

A CHAPTER IN THE HISTORY OF THE MARCONI BEAM—I - - - - - - - - „ 3

PORTABLE SHORT WAVE MILITARY TRANSMITTER AND RECEIVER. TYPE S.A.1 - „ 13

DISCUSSION ON SHORT WAVE FADING—I - „ 23

MARCONI NEWS AND NOTES—
BEAM WIRELESS ACHIEVEMENTS
AIRCRAFT WIRELESS - - - - - „ 29

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THE MARCONI REVIEW

October, 1928

FOREWORD

By SENATORE G. MARCONI, G.C.V.O., LL.D., D.Sc.

IT is a very great pleasure to me, as one of the very few persons still living who has been intimately and continuously associated with the development of Radio Science and Art from its earliest inception, to wish all possible success to the "Marconi Review."

In a period of little over thirty years, "Wireless," as we first called it, has exceeded even my expectations, by not only establishing itself at sea and on land as the most direct and rapid method of long distance telegraphy and telephony, but also by entering the home through Broadcasting, and thereby becoming the most universal and potent method of instantaneous communication which the world has ever known.

By its latest telegraphic and telephonic developments, Radio has given us a permanent system of International and Imperial communication to which distance is no obstacle. It has multiplied in a most wonderful manner our possibilities for disseminating, extending and receiving instruction and entertainment; it has reached out to the Opera, the Stage, the Concert Hall and the Pulpit. It has entered the Motion Picture industry with its system of synchronous sound and sight; it has allied itself with photography through photo-radio and facsimile transmissions; and now it is going to give us Television, and perhaps, some day, transmission of power, besides other things which we most probably are unable even to foresee at the present time.

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Although I find it quite impossible to visualize any definite limit as to what more may be achieved in even the not far distant future, I feel convinced that further rapid progress must be dependent in no small measure on a still closer relationship between industrial attainments and advanced Scientific Research. Without the aid of pure Science and Scientific Research, Radio would not now be in existence, but at the same time we must also recognise that without the powerful means, and encouragement which Industry, or even the hope of industrial success, have been able to place at the disposal of Radio research, many of the far reaching discoveries and inventions, which alone have brought it to its present position as a world-wide factor, might not have been made, or might have been delayed for generations.

One of the principal objects of this new Review is to make known what is being achieved by the combination of Industrial and Scientific Research, and to endeavour to show that swiftly moving scientific progress and rapid technical advance, which together can bring about achievements useful to mankind, demand industrial flexibility rather than industrial stabilization.

It may also help to demonstrate that progress in the Radio Art is not only dependent on the genius, intuition, and learning of the scientific workers, but also on the courage, intuition, flexibility of mind, and self-protecting progressiveness of the executives who happen to be in control of great industrial and commercial enterprises.

G Marconi

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A CHAPTER IN THE HISTORY OF THE MARCONI BEAM

Less than two years ago, in October, 1926, the first Imperial Wireless Beam Service operated on the Marconi System was inaugurated between Great Britain—with stations at Bodmin and Bridgwater—and Canada, with stations at Drummondville and Yamachiche, and following each other at short intervals, a number of other Imperial Wireless Marconi Beam services have since been opened, which, at the present time, not only girdle the globe, but have revolutionized the art of radio communication; and they are all commercially successful.

Apart from its many long wave wireless services with foreign countries, the strategical position of Great Britain as regards long distance Imperial wireless communication, previous to 1926, was weak. Great Britain was only in direct two-way wireless communication with one Dominion (Canada) and one Protectorate (Egypt). To-day, thanks to the Marconi Beam, no other nation is so well served by wireless for defence or commerce. These results provide a fitting conclusion to a remarkable chapter in the history of wireless development, the details of which are discussed in the following article.

EARLY in 1924 the Marconi Company put before the British Government its proposals for an Imperial Wireless network based on the Beam system, and by abandoning the use of high-power long wave wireless stations in favour of low-power short wave Beam stations for transmission over maximum world distances, announced a change of policy radical enough to appear dramatic, involving as it did a complete departure from traditional long wave design in every feature of the installation, and employing for propagation to a very much greater extent the characteristics of the uncharted regions of the upper atmosphere with their known variability, in preference to the more stable characteristics of the lower atmosphere favoured by long waves.

Although the decision followed so quickly on the report of the successful results of Senatore Marconi's tests on the S.Y. "Elettra" as to suggest that there had been scarcely time enough to give sufficient consideration to the possible difficulties involved, the position had really been very carefully studied in the light of a mass of data which had been steadily accumulating, and was surprisingly complete at that date, having regard to the very wide area of research which the short wave Beam development had opened up.

In point of fact, there had been overlapping development in both long wave and short wave working for some years.

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Mr. C. S. Franklin's paper on "Short Wave Directional Wireless Telegraphy," read before the Institution of Electrical Engineers in May, 1922, gives a fairly complete history of the research work which had been done on short waves and reflectors up to that date. But no one but Senatore Marconi and his assistants had been working in this field. As Senatore Marconi himself pointed out in a paper on "Radio Telegraphy," read in June, 1922, before a joint meeting of the American Institute of Electrical Engineers and the Institute of Radio Engineers, practically all through the history of Wireless, the study of the characteristics and properties of short electrical waves had been sadly neglected, and when he resumed his work in 1915 it was because he could not help feeling that by confining all experimental work to long waves, research workers had perhaps got into a rut, and that further investigation of short wave phenomena was likely to develop in many unexpected directions and open up new fields of profitable research.

How true this forecast was we now know, but at that date the general view was that the application of short waves and reflectors was limited to short distance work only.

In 1923-1924, however, the rate of progress with the research and experimental work, although it covered valve design, new short wave circuits, aerials, reflectors and receivers, was so rapid and satisfactory, finally reaching a climax with the successful long distance tests between Poldhu and the S.Y. "Elettra," that the Marconi Company was enabled to present a strong case for the consideration of the British Government at a moment which proved opportune, and before too much expense had been incurred in the erection of the high-power long wave Imperial Stations.

Long Wave v. Short Wave.

It will be remembered that following the findings of the Government Committee in 1923, that the British Post Office should own and operate directly all wireless stations for communicating with the various parts of the British Empire, the Post Office commenced the erection of the Rugby high-power long wave station, and the Marconi Company, in agreement with the Dominion Governments, put in hand the erection of stations, either of their own or in partnership with these Governments, of somewhat similar size in Australia, South Africa, and India, each employing 800-ft. self supporting aerial towers and a 1,000 kw. transmitter designed to work on wavelengths of 20,000 to 30,000 metres, at a cost per installation of about £500,000.

But wireless research has always been unconfined and has never stagnated. While these super stations were actually under construction and the solution of the big problems they presented to receiver experts of providing for the reception of heavy traffic on a varying field strength and above the high noise level and inter-

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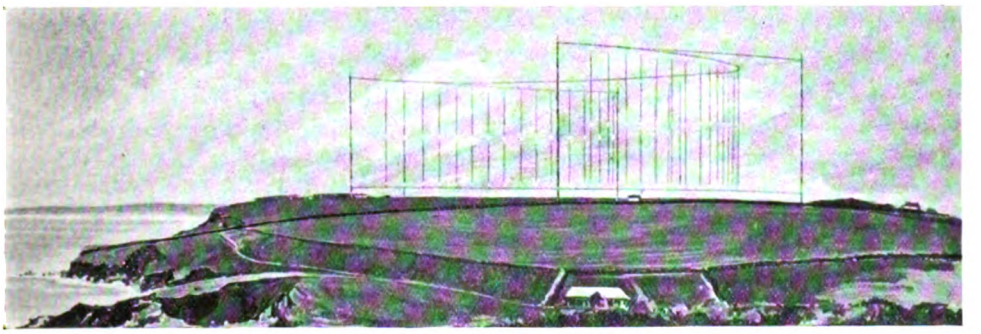

FIG. 1.—*Poldhu Experimental Beam Station.*

ference associated with long wave working was receiving the closest attention from the Marconi Research Staff, Senatore Marconi himself was obtaining results on the S.Y. "Elettra," on his short wave tests with Poldhu which held out possibilities of future development that could not be ignored.

The object of the first series of tests carried out in April, May and June, 1923, was primarily to note the results when the Beam principle was applied on a large scale, and was a continuance—as foreshadowed in Senatore Marconi's 1922 paper—of the earlier research work on reflectors when wavelengths of 3, 6 and 15 metres had been employed.

While carrying out some duplex telephony tests across the North Sea between Southwold and Zandvoort in August, 1921, employing a 100 metres wavelength with about 1 kw. to the aerial, it was found that good speech could be received every night and sometimes during the day at Oslo, some 450 English miles distant, and in choosing a wavelength for the tests at Poldhu these results carried some weight, particularly as 100 metres wavelength appeared to be about the maximum limit one could use with reflectors of practicable dimensions. The logical order of testing also was to try out the longest wavelength first, particularly as it was then generally believed that the shorter the wavelength the less was the daylight range.

The height of the Poldhu masts was therefore increased to 325 ft. and allowing for the sag of the triatics supporting the reflector wires which fixed the maximum height of the reflector, the relation between the length of the reflector wires and the half wave aerial resulted in the wavelength finally used at the start of the tests being 97 metres. A view of the system is shown in Fig. 1.

The test procedure was as follows :—

(1) Transmission took place at Poldhu.

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(2) Polar curves of field strength were taken on land at several wavelengths distant from the transmitter.

(3) Field strengths were measured on Senatore Marconi's yacht at different distances up to the maximum practicable, and also across the width of the Beam.

(4) Reports of signal strength were also obtained in the later tests from stations in different parts of the world.

Not only did the reflector experiments as such give very encouraging results, but the 97 metres wavelength proved to be unexpectedly efficient.

All previous long distance tests on short wave—that is on wavelengths of 200 m. and less—had been carried out during the hours of darkness on very low power, with critical adjustments of transmitter and receiver, and had given results of extraordinary variability which were generally considered freakish and quite unsuitable for traffic purposes. But Senatore Marconi's "Elettra" tests showed that with well designed apparatus which was stable in operation, and with a reasonable amount of power supplied to the aerial, much of the variability of the transmission disappeared.

Not only could a good night range be obtained, but atmospherics were found to be comparatively weak, and the day range also was considerable.

The signals at St. Vincent, 2,300 nautical miles from Poldhu, even with the input power reduced from the maximum of 12 kw. to 1 kw., were found to be so much above the noise level as to justify the belief that a reliable commercial service could have been carried on between these two points for the greater proportion of the 24 hours.

At the end of a report to the Directors of the Marconi Company on the results of the S.Y. "Elettra" receiving tests, dated 12th June, 1923, Senatore Marconi wrote: "I have little doubt, however, that with our present knowledge and with stations using only about 12 kw. it would be possible to maintain daily a 10 to 14 hours' service between Europe and Brazil, and, perhaps, even with the Argentine."

Short Wave Beam Proposed for Imperial Stations.

As nothing like such good results could be expected from any form of commercial long wave transmitter using the same small power and employing the same low effective height of aerial, the Marconi Company which for 17 years had made it its mission to insistently keep the problem of Imperial Communications in front of the attention of the Government of the day, and holding the unique position of being the only authority in the world able at that time to weigh up from the results of practical experience the probable advantages and disadvantages of the long wave

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and short wave methods of transmission when applied to long distances, in both of which it was vitally interested, after earnest consideration submitted a proposal to the British Government for the employment of the short wave Beam at the Imperial Stations.

Already the range achieved was great enough to satisfy the requirements of the 1919-1920 Imperial Wireless scheme, which contemplated the employment of relay stations 2,000 to 2,800 miles apart, and the short wave signals at St. Vincent were stronger and more free from interference than those received from the first of these long wave stations opened at Leafield by the Post Office in 1921, and which employed a 250 kw. arc transmitter.

A very wide field of investigation was opened up as a result of these negotiations, and before contemplating a change of wavelength other no less important factors had to be considered.

The programme for the further trials between the S.Y. " Elettra " and Poldhu, which took place in the spring of 1924, therefore included the systematic testing of improved receiver and transmitter circuits, increasing the power of the transmitter up to 20 kw. by the aid of cooled anode valves specially made for these tests, and the testing out of various modifications of the aerial and reflector system, also, what was of supreme importance, the collection of reports on the results of the transmission as received at Montreal, New York, Rio de Janeiro, Buenos Aires and Sydney, N.S.W.

Government Contract Signed.

With the receipt by Sydney of ordinary telegraph signals on the 3rd April, 1924, even without a reflector, and telephony a month later, the expectation that the short wave transmission would be received at the antipodes was fulfilled, and the British Government—which had appointed a sub-committee of the Cabinet to examine the proposals put forward by the Marconi Company—no longer hesitated to conclude an agreement with this Company for the construction of wireless stations on the Beam principle, of 20 kw. to the valve anodes, for communicating with Canada, South Africa, India and Australia, which was signed on the 28th July, 1924. Acceptance was to be conditional on a continuous seven days' test working duplex, at not less than 100 words per minute simultaneously both ways, and exclusive of any repetitions necessary to service accuracy, for 18 hours per day on the Canadian circuit, 11 hours on the South African, 12 hours on the Indian, and 7 hours on the Australian circuits.

Considering what little was actually known at that date of the transmission characteristics of different parts of the short wave spectrum, the clauses as to high speed working and the number of hours per day the stations must communicate, appeared to be very onerous for the Marconi Company. So much apparently

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depended on what happened to the waves in the upper regions of the atmosphere, and this was a question on which experts disagreed.

It was one of those critical occasions which sometimes occur in the life of a great public Company. Events had compelled a quick decision on a question of great moment, and the effects would be far reaching. Technical as well as commercial risks would have to be faced, and liabilities incurred, which included the scrapping of large assets of the long wave stations and heavy expenditure on research and development for the new short wave stations. In 1923 the Imperial scheme, for which the Marconi Company had laboured so long, was in process of realisation, but in the light of the research work of 1923 and 1924, the long wave stations projected would have probably been out of date before they were completed, so that in the view of the Marconi Company events were only being anticipated by the Beam contract, and the whole weight of the Company's resources was now concentrated on the achievement of this undertaking.

The Position in July 1924.

The position, from the point of view of the Marconi Company, was as follows :—

(1) The beam had proved to function as a beam at a very considerable distance.

(2) The 100 metre wave over a long distance had proved to be unexpectedly efficient.

(3) It had been shown that the new type of cooled anode power valve could be employed in short wave transmitters.

(4) Signals could be received at the greatest distances by short wave.

The points that remained yet to be determined were :—

(1) The number of hours per day that communication would be possible at different periods of the year in the various countries.

(2) The complete specification of the transmitting constants in terms of the aerial power, wavelength, and angular width of beam required to maintain signals at sufficient strength to provide the average speed of working for the requisite number of hours per day.

(3) The development of keying and recording apparatus which would function with the minimum of attention and renewals at speeds providing a wide margin above that of the guaranteed average speed of working, in itself a problem of no small magnitude.

It was known that on short wave it should be theoretically possible to work at much higher speeds than on long wave, and it was expected that the speed of 70 or 80 words per minute,

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which at that date was about the practical limit for long wave, although a higher speed was possible, would have to be increased up to 200 or even 400 words per minute if the hours of working on the beam proved to be too short to enable the traffic to be cleared otherwise.

The undeveloped possibilities in reserve were :—

(1) The certainty of improving the efficiency of the transmitter, the amplification and selectivity of the receiver.

(2) The strong probability that by further research the aerial and reflector systems could be made more efficient.

(3) The possibility of obtaining still more favourable propagation characteristics by working on a wavelength or wavelengths yet to be determined, other than 100 metres.

Very little however was known of the adaptability of short waves for long distance transmission, the mechanism of propagation was not understood, it was too early to draft any empirical or working formula, and a definite technical risk had to be faced that further research might not give more favourable results. Relying therefore mainly on the effectiveness of the Beam principle, that at long distance the wave energy would still remain concentrated within a narrow angle, the power to the aerial, and the efficiency of the receiver—the Marconi Company accepted this technical risk as one of those unavoidable unknown factors which have to be reckoned with in many a good business enterprise.

The progress made in beam development during the period 1923-1924 covered by that section of the Poldhu—" Elettra " tests, which were carried out previous to the signing of the agreement with the Post Office, can be summarised as follows :—

TECHNICAL DEVELOPMENTS

The Reflector.

The employment of parabolic cylindrical reflectors of sheet metal had for some years been superseded by the use of reflectors of similar shape composed of a number of vertical wires separated about $\frac{1}{8}$ to $\frac{1}{10}$ wavelength apart. The focal distance of the parabola was made equal to either $\frac{1}{4}\lambda$ or $\frac{3}{4}\lambda$, and the aerial was placed at the focus of the reflector.

It was an accepted principle that the reflector should be large compared with the wavelength, and it had been proved that long reflector wires gave best results when broken up into a series of insulated half-wavelengths.

The divergence of the beam within the distances covered by the " Elettra " tests was proved to agree with the angle calculated, and was a function of the aperture of the reflector in terms of wavelength.

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To obtain a 10° beam on a 100 m. wavelength with a parabolic reflector necessitated an aperture several wavelengths wide, involving a costly structure of supporting masts covering a large area of ground, and this cost would militate against the commercial success of the system. An endeavour was therefore made by Mr. C. S. Franklin to obtain a narrow beam of radiation by other means. This resulted in the first mesh aerial which was referred to in Senatore Marconi's paper read at the Royal Society of Arts on the 2nd July, 1924. It consisted of a number of vertical wires, Fig. 2, divided into half-wavelengths by condensers, connected together by horizontal wires of suitable length, and resistances where necessary so that the currents in the vertical parts were all in phase, when the resultant field produced a highly directive radiation at right angles to the plane of the mesh. The back radiation could be used to reinforce the radiation in the direction required by employing a similar system spaced a $\frac{1}{4}$ or $\frac{3}{4}$ wavelength behind the first, as a reflector.

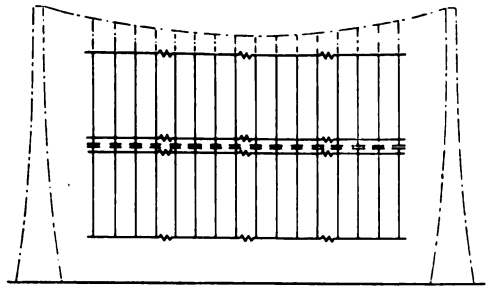

FIG. 2.

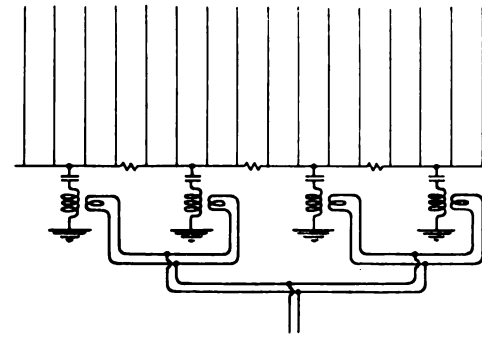

FIG. 3.

The limitation imposed on the concentration of the beam by the economic restriction on the size of parabolic reflectors was removed by adopting this type of construction, the ground area covered by the masts, reflector and aerial for a system of 2 wavelengths' aperture being now only $\frac{1}{10}$ what was formerly required.

The Aerial.

As in previous reflector tests, the Poldhu transmission commenced with the employment of a $\frac{3}{4}\lambda$ aerial, the lower part of which was non-radiative and coupled to the transmitter.

Attempts had been made to restrict the radiation in the vertical plane as well as in the horizontal plane by combining two half-wave oscillators at right angles and exciting them in quadrature, to produce a circularly polarised wave—and experiments had been made with a paraboloid reflector instead of a cylindrical parabola, with the same object, but the best practical result eventuated from a development of the mesh aerial, wherein the vertical half-wave components, one

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above the other in series in the mesh when brought into phase, had the effect of concentrating the radiation to a certain degree in the vertical field in a similar manner but to a less extent than the concentration effected in the horizontal field by the in-phase currents in the much more numerous and wider spaced parallel wires along the width of the aerial.

The Feeder System.

With the introduction of the mesh or multi-aerial system, the problem of coupling to the transmitter was no longer a simple one.

The single wire aerial employed with the parabolic reflector could be coupled at its base direct to the transmitter, but to obtain currents in equi-phase throughout the mesh it would have to be fed at several points, and this necessitated the employment of an intermediate coupling circuit. A coupling circuit several wavelengths long had been used with success between the half-wave antenna and the receiver on the S.S. " Royal Scot " during the Inchkeith tests, on a 4 metres wave in 1922, and, proceeding on similar lines, a suitable feeder circuit was evolved for the mesh aerial.

During the 1924 tests the mesh was sometimes fed at four points, Fig. 3, and sometimes at eight, so that part of the aerial was fed direct, but part had to be fed through other parts, the feed therefore having a series parallel character. At a later date the transverse connections of the mesh aerial were finally abandoned, leaving the simplified system of vertical aerials only, and the series feed gave place to an all parallel feed, which gave greater stability of direction to the beam.

It is interesting to note that the mesh aerial and the series feed, which, as mentioned above, were intermediate stages in the development of the Franklin aerial to its present type, have since been revived on the Continent and in America, and necessarily retain the defects which caused these methods to be abandoned by the Marconi Company.

The Power Valve.

The standard type of transmitting valve, which was satisfactory for long wave service, developed trouble at the seals when used on short wave, and the eight air-cooled valves, each taking 1½ kw. at the anode, employed in the 100-meter 1923 Poldhu tests, were specially made for the work. This was provisional. The water-cooled anode valve for long wave work was first placed on the market in 1922, and its design was modified by Franklin so that it could be used on short wave and with anode cooling by oil circulation, and these new valves, each taking 10 kw. at the anode, were ready for the tests carried out in the spring of 1924.

The Transmitting Circuit.

The eight air-cooled valves, each with its own oscillating circuit, were mounted in two metal panels providing good screening, and were used all in parallel to form

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a simple self-oscillator. This was only an experimental circuit, however, and as soon as the oil-cooled valves became available, four of the air-cooled valves were employed as before to form a self-oscillating drive circuit, while two oil-cooled valves were employed in the new bridge circuit forming a power amplifier, wherein the transmitting valve capacities were for the first time balanced out, see Fig. 4.

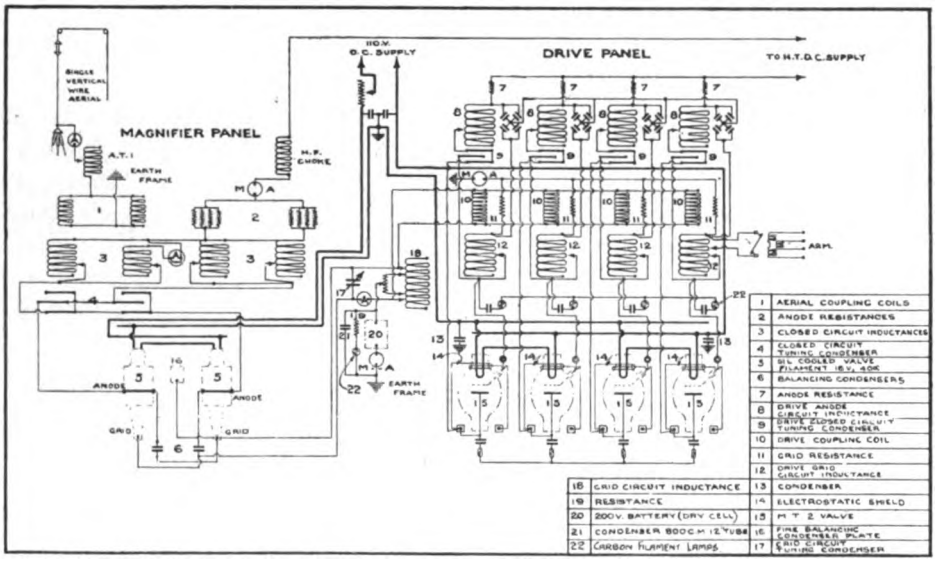

FIG. 4.

By this change, the transmitter benefited by an increase in power, in stability as an oscillator, and in constancy of wavelength.

(To be Continued)

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SHORT DISTANCE COMMUNICATION

MARCONI PORTABLE SHORT WAVE MILITARY TRANSMITTER AND RECEIVER—TYPE S.A.1

There is a constant need for some easy method of communication over short distances, on land and sea, by means of light, compact, and easily handled wireless equipment. The Marconi 25-40 watt short wave portable transmitter and receiver, which is the outcome of several years' intensive research, meets this need in the most effective manner.

For military purposes it has the following important features :

1. *Secrecy.*
2. *An almost invisible aerial system.*
3. *Simplicity and ease of operation.*
4. *Compactness and portability.*

These advantages render the set particularly suitable for use as a trench set and for other short distance military communications.

The normal aerial is only 12 feet (3.75 metres) in height, and this may be reduced by approximately one-half if desired.

The aerial and transmitter are connected by a feeder cable so that the aerial can be erected in any convenient spot and the set itself placed in a bombproof shelter.

The total weight is only 155 lbs. (70 kilos.), and it can be carried either by wheel transport or on pack animals.

Owing to the short wavelength employed a number of these stations can be used on a limited front without causing interference.

It is not surprising, therefore, that there has been a great demand for these sets in all parts of the world.

THE S.A.1 Transmitter and Receiver are designed for military communication, especially under conditions of war. The wavelength used varies from 7-8 metres, many advantages arising from the use of these very short wavelengths. It must not be supposed, however, that because the waverange of the transmitter covers only from 7-8 metres, the waverange is small. If we consider the waverange in terms of kilocycles, we can see at once that the minimum frequency is 37,500 kc., and the maximum frequency is 42,860 kc. The range of frequencies then is very large, and actually corresponds in, say, a 300 metre set to some hundreds of metres. Hence a considerable number of stations can work in the 7-8 metre band, even though they are all close to one another.

The equipment includes all necessary apparatus for transmission and reception, including the generator for the transmitter, all batteries, etc., for this generator and for the receiver, spares, and aerial system.

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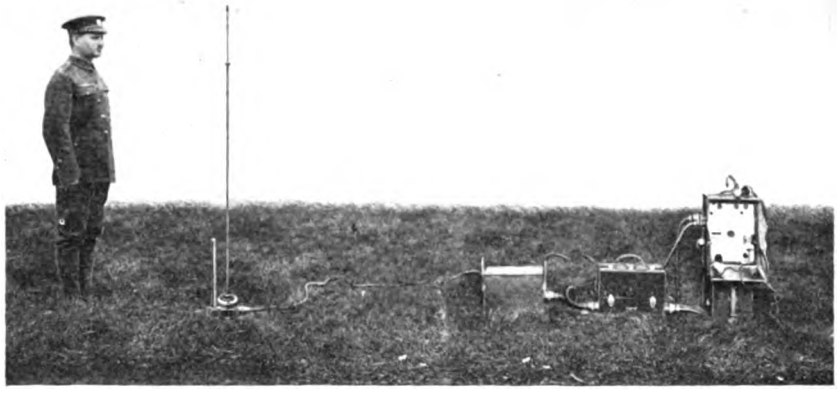

Type S.A.1 Set with Quarter Wavelength Aerial ready for Operating.

The Transmitter.

The transmitter is constructed for both Tonic Train, or I.C.W. transmission, and telephony. The approximate effective range of the transmitter for Tonic Train is, in the case of the half wave aerial 8 miles, and in the case of the quarter wave aerial 4 miles. For telephony these ranges are approximately 6 miles and 3 miles respectively. The figures given above correspond, of course, to general performance. Certain freak results must, however, be expected with the use of wavelengths of this order of magnitude, and the ranges given may be greatly exceeded on occasions.

The oscillator of the transmitter (Fig. 1) is of the Franklin Type, and is made as simple as possible. This oscillator is grid controlled for telephony by means of a microphone transformer and microphone, and has its grid circuit broken by a rotary interrupter mounted on the shaft of the generator for Tonic Train.

As the transmitter itself is of such a simple nature, we shall spend but little time in describing its action and proceed to a brief discussion of the aerial system which is one of the chief features of the set.

A diagram of the connections of the transmitter is given below (Fig. 1) and the simplicity of the circuit will be at once apparent. In all work on short waves, it is found that the simpler the circuit, the better the results which are obtained from it.

In the type of self-oscillator used in this transmitter we have, in addition to the small incidental magnetic coupling between the two coils A and B (Fig. 1), the capacitative coupling provided by the Condenser G, which is made variable to permit of variation of wavelength. It is to be noted, however, that, even in the circuit

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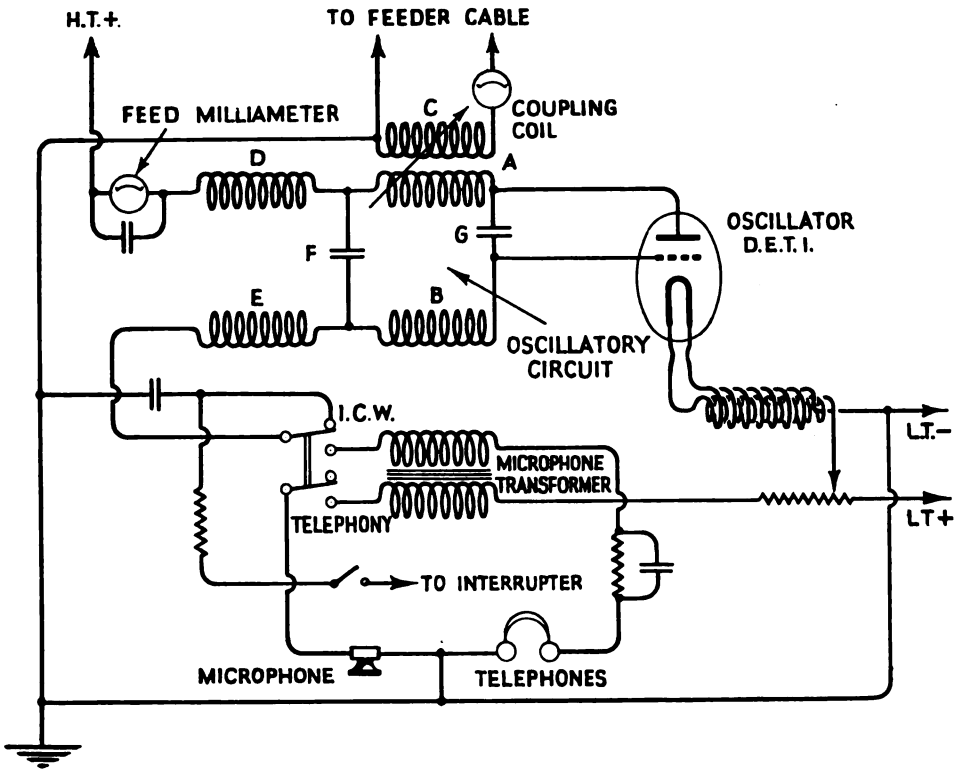

FIG. 1.

shewn below (Fig. 2) (a simple tuned anode oscillator) we have a certain amount of capacitative coupling between the coils due to the capacity existing in the valve itself between the grid and anode.

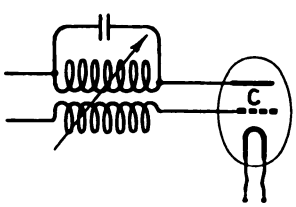

FIG. 2.

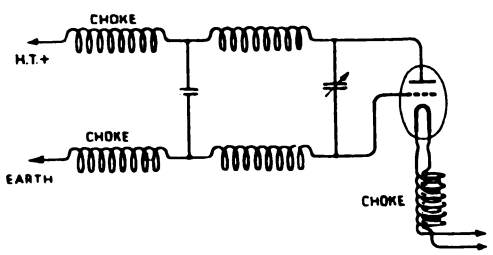

FIG. 3.

The condenser F (Fig. 1) serves to complete the H.F. circuit and to render the reactance across the generator negligible.

If the inductance of A is L_1, and that of B is L_2, and if M is the mutual inductance

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between the two coils, should there be any, then the frequency of the oscillation generated will be given by

$$\omega = 2\pi f = \frac{I}{\sqrt{(L_1 + L_2 - 2M)\,C}}$$

where C is the capacity value of the condenser G, added to the valve grid to plate capacity.

The method used for modulating the oscillator is known as the grid control method, and is undoubtedly the best and simplest method of modulating small power transmitters. The general arrangement of the microphone circuit is given above (Fig. 3). If the microphone is idle, the high frequency current from the oscillator will be constant, but if the microphone is excited by sound waves, a changing current will be produced in the primary of the microphone transformer which will be passed to the grid circuit through the secondary of the transformer. Hence the grid of the oscillator will have the low frequency E.M.F. of the secondary impressed upon it in addition to the high frequency E.M.F. of the oscillatory current. A modulated current will thus be radiated which will be a function of the sound waves impressed on the microphone.

The advantages of this scheme of modulation lies in the fact that the microphone need only be of very small current carrying capacity. Hence quite a large oscillator can be modulated with a small microphone.

The microphone transformer has its primary winding arranged to match the impedance of the microphone and its secondary winding to suit the grid-filament circuit of the transmitting valve.

As we have stated above, the grid circuit is broken at a constant frequency for the transmission of Tonic Train, and no special explanation need be given of the method employed. Oscillations are simply started and stopped at the frequency of the interrupter on the rotary converter.

A coupling coil is provided to couple into the anode coil of the oscillator to supply the aerial. One side of this coupling coil is earthed, and the other side has a hot wire ammeter in series with it and the feeder cable to read the feed current. We shall refer to this coupling coil later.

Chokes D and E (Fig. 1) are provided to prevent H.F. energy from getting back to earth and so being dissipated. A double astatic choke is provided in the filament circuit for the same purpose. The grid has a suitable bias applied to it by means of resistances connected between the grid circuit and earth. A milliameter, shunted by a condenser to bye-pass H.F. currents, is provided to enable

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the feed of the oscillator to be observed, and switches are provided for the change over from Tonic Train to Telephony and *vice versa*.

This description suffices to shew the general behaviour of the transmitter itself, and we shall now proceed to deal, rather more in detail, with the aerial system.

Aerial System.

The aerial system of the S.A.1 transmitter can be conveniently divided into four sections :—

1. The coupling coil and its transmitter.
2. The feeder cable.
3. The balancing coil.
4. The aerial.

1. The coupling coil from the transmitter consists of 5 turns of wire wound on a 1½ inch ebonite former with ¼ inch spacing, and is variably coupled to the main oscillatory circuit. As we shall see later, this coil and the circuit coupled to the coil constitute one of the terminal impedances of the feeder cable, and this input impedance is therefore a point to be considered when the feeder cable is discussed. Apart from this point, no special attention need be paid to this coil.

2. The feeder cable consists of a lead covered cable, some 23 feet long, with the lead covering effectively earthed to the transmitter and aerial. The inner conductor is attached to the coupling coil at one end, and to a tapping on the balancing coil at the other. The whole feeder system now resembles that shewn in Fig. 4.

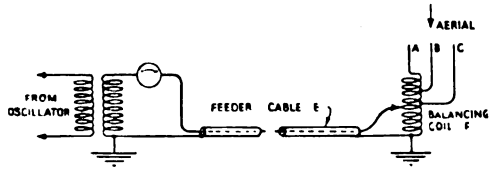

FIG. 4.

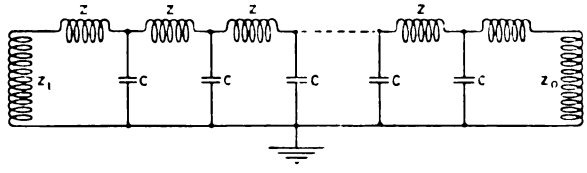

FIG. 5.

Now such a lead covered cable, terminated at its two ends by impedances (which are, of course, the coupling coil and its associated circuits at the input end, and the balancing coil and its associated circuits at the output end) can be repre-

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sented by a series of sections as shewn in Fig. 5, where

Z_1 = impedance of coupling coil, and oscillator circuit coupled to it.
Z = inductance per unit length of feeder cable.
C = capacity ,, ,, ,,
Z_0 = impedance of balancing coil, and aerial circuit.

If a current be impressed on one end of this system, it will, in general, be propagated along the system meanwhile undergoing certain changes. These changes are

1. Attenuation.
2. Distortion.

We shall deal here only with the first ; distortion occurs only to a slight degree, and is not of primary importance as regards the transmitted signal. When the input current has reached the output end, a fraction of it, which we shall call Y, is reflected back again in an opposite direction, and the rest is delivered to the aerial. This fraction Y now proceeds to the input end, where a part of it, say X, is again reflected. This process continues indefinitely. We see then that stationary waves are set up in the feeder system, owing to these reflections ; and that these stationary waves indicate loss of useful energy. Now it may be shewn that

$$X = \frac{Zs - Zi}{Zs + Zi}$$

$$Y = \frac{Zs - Zo}{Zs + Zo}$$

where

Zs = a quantity known as the surge impedance of the system. This quantity is actually the impedance of the system neglecting the input and output terminal impedances.*

Now the idea of the feeder cable is to transmit the energy from the oscillator to the aerial with as little loss as possible.

This must be accomplished by

(A) Making the output terminal impedance equal to the surge impedance of the line, i.e. making Y=0 ; thus ensuring maximum transference of energy from line to aerial by preventing reflection and consequent stationary waves.

(B) Adjusting the input terminal impedance by altering the coupling to get the required output and efficiency from the transmitter.

Let us next consider the aerial itself. This consists of a straight rod AB (Fig. 6), with a flexible lead which can be attached at varying points on the inductance D, one end of this inductance being earthed.

* Zs for a system of this type $= \sqrt{\frac{L}{C}}\sqrt{1 - \frac{1}{4LC\omega^2}} - \frac{jR}{L\omega}$ where R = resistance per unit length of feeder cable.

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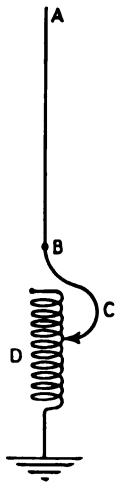

FIG. 6.

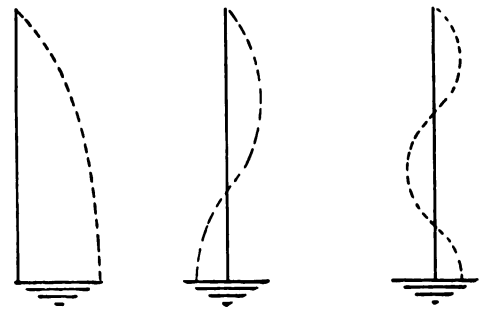

FIG. 7.

In such a vertical aerial wire it is obvious that the top end must be a node of current and a loop of potential. Conversely since the bottom end is earthed, it must be at zero potential, and there will be a loop of current. It can be shewn from this that we wish the aerial to resonate (i.e. to radiate maximum energy) at a wavelength λ, the effective length of the aerial and loading inductance must be

$$\tfrac{1}{4}\lambda\ ,\ \tfrac{3}{4}\lambda\ ,\ \tfrac{5}{4}\lambda$$

or some odd number of quarter wavelengths.

The instantaneous values of current for these aerials are shewn in Fig. 7, and the corresponding voltage curves in Fig. 8.

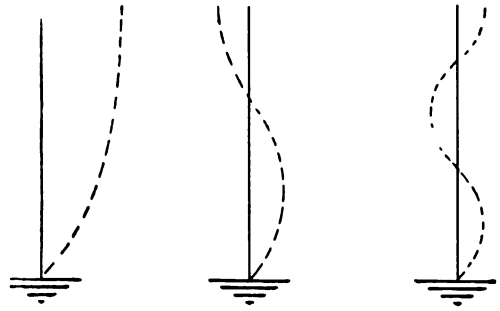

FIG. 8.

Hence we can easily see that, if the effective length of the aerial itself is $\frac{\lambda}{2}$, we must add inductance D to make the effective length of the whole system $\frac{3}{4}\lambda$. We shall then have a state of affairs as represented below (Fig. 9). If we consider any point P, some distance from the transmitter, we shall have the

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intensity from a point B on the aerial partially neutralising the intensity from a point A, since in one case the intensity is negative, and in the other case it is positive. Hence with an aerial of more than $\lambda/2$ long, we shall have a comparatively weak field. We have therefore two alternatives :—

1. To make the aerial exactly $\lambda/2$ long.
2. To prevent the part CB of the aerial radiating.

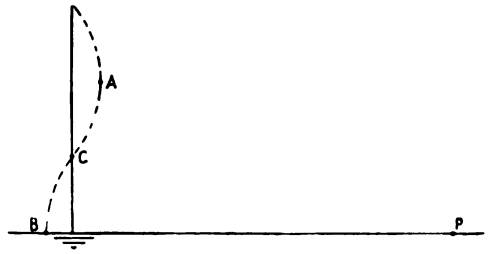

FIG. 9.

The second method is adopted in the case of the S.A.1 set. The coil in which the part of the current curve represented by CB takes place is shielded by an earthed screen and is thus effectively prevented from radiating.

Two aerials can be provided for use with the set. One of these is almost exactly $\frac{\lambda}{2}$ long, and is loaded to give an effective length of $\frac{3}{4}\lambda$. The other is slightly less than $\frac{\lambda}{4}$ and is loaded to give an effective length of $\frac{\lambda}{4}$.

The use of short waves has many advantages for such a set as the S.A.1. Firstly we can energise the aerial effectively, as an aerial of $\frac{\lambda}{2}$ in length is quite convenient to handle. Secondly, the $\frac{\lambda}{2}$ aerial is of such dimensions as to be practically invisible at short distances. Thirdly, the aerial itself can be placed in a position on the top of a trench or outside a dug-out where it forms an effective radiator and by the use of the feeder cable the set and operator can be safely housed below ground. Fourthly, the traffic on such a short wave is not liable to be picked up accidentally as might be the case if the transmission were made on, say, 300 metres, finally, on such short wavelengths interference from atmospherics is negligible and consequently combined with the present-day freedom from jambing on these wavelengths, communication under all conditions is very much more certain than is the case with any wavelengths of a lower order of frequencies.

S.A.1 Receiver.

The receiving system employed in the S.A.1 set is a modified form of Super-Regenerative circuit, and combines very great magnification with perfect stability. The control of the receiver is remarkably simple, and the tuning is very selective without being too sharp for manipulation.

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There are three valves in the receiver. The first, a D.E.Q., operates as an autodyne detector, as will be explained later. The second operates as a long wave oscillator, and the third operates as a simple note magnifier.

The general theory of the receiver is as follows :—

In an autodyne or heterodyne detector, when continuous wave signals are being received, it can be shewn that the following relation holds.

$$\Delta I_p = \frac{EE^1}{2} \cos(\omega - pt) \frac{d^2I_p}{dE^2}$$

where

ΔI_p = change in plate current.

$E^1 \cos \omega t$ = periodic E.M.F. produced in grid circuit of valve by self oscillation.

$E \cos pt$ = periodic E.M.F. impressed on grid circuit of valve by C.W. signal.

For ordinary continuous wave reception, p is made very nearly equal to ω. In this case $\cos(\omega - pt)$ fluctuates very slowly, and produces an audible signal in the telephones which are in the anode circuit of the valve.

Now, from the above equation, it seems that the more violently the valve is oscillating (i.e. the larger E^1 is made), the more sensitive will the valve act as a detector. Actually the more E^1 is increased the smaller does $\frac{d^2I_p}{dE^2}$ become. Hence some condition must be found to give the best results, and it is found that, in general, the product $E^1 \frac{d^2I_p}{dE^2}$ will be a maximum for the condition in which the valve is just on the point of starting oscillating. In ordinary receiver practice one works to this point, when receiving damped signals such as we are dealing with here.

In Fig. 10, a curve is given shewing the variation of I, the signal intensity, with reaction M. Examination of this figure shews that if we could work past the critical point into the region of oscillation very greatly increased amplification would result, but some method would have to be found to prevent distortion of the signal. In the super-regenerative circuit distortion is prevented by rapidly quenching the oscillations at an inaudible frequency.

Actually the method used is as follows. The signal is impressed on the grid of the detector by means of a coupling coil G (Fig. 11), in series with the aerial system. The detector is arranged so that the coupling between A and B is just insufficient to start the tube oscillating with normal H.T. voltage. The whole input circuit is tuned by means of the condenser C to the wavelength required.

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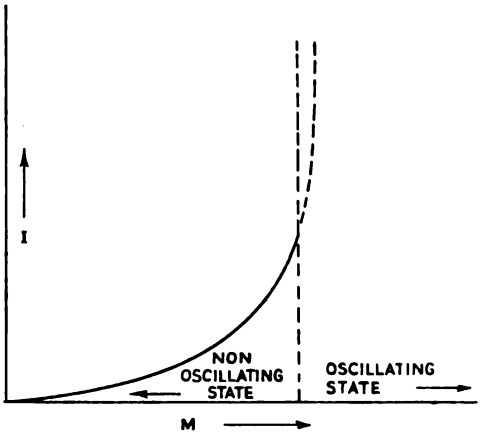

FIG. 10.

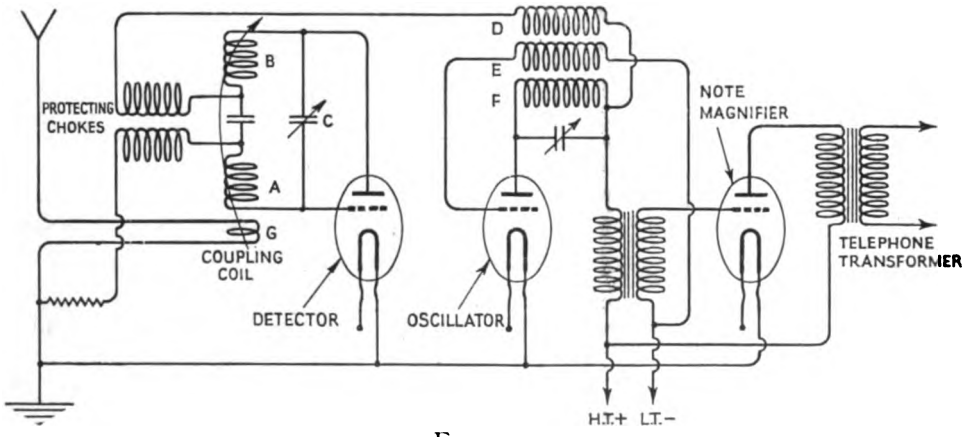

FIG 11.

The oscillator is simply a tuned anode oscillator tuned to about 20,000 $\sim$ per second. A coupling coil D is in series with the H.T. supply to the detector. When the oscillator impresses a varying E.M.F. on this coil, the H.T. voltage on the detector is varied at a super-sonic rate, and causes this valve to start and stop oscillating, at a frequency of 20,000 $\sim$ per second.

In this way enormous amplification is obtained, and yet no audible distortion of the signal occurs ; for the valve is only unstable for lengths of time which are too short to be heard.

The rectified signal is further amplified by means of a transformer coupled note magnifier, and taken to an output transformer, and from thence to the telephones.

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A DISCUSSION ON SHORT WAVE FADING

Fading is examined on the assumption that it is produced by the accidental interference of two or more rays. The mean square variability is calculated, and a comparison with observed results shows that the actual variability is more than twice the calculated value.

A calculation is made of the reduction in variability occasioned by the addition of the rectified signals from two spaced aerials on the assumption that the effects in these two are statistically independent. These results show that the variability should be approximately halved.

A better comparison of the gain on using two aerials is obtained by comparing the number of fades to less than a prescribed fraction of the mean signal strength on the single and double aerial system. If this prescribed value is 38 per cent. of the mean signal strength, a gain of the order of 20 to 1 accrues, that is, if there are twenty fades per hour in the single aerial case, there will only be one when using the combined results of two aerials.

THE chief problem of short wave transmission is undoubtedly fading, as the interference due to atmospherics on the short wave band is practically negligible.

At the outset, it is suggested that there are two types of fading which must be considered. There are the long fades of half an hour to hours at a time, and the short fades of a minute to fractions of a second. The long fades of half an hour up to whole days at a time, which occur during magnetic storm activity, are almost certainly due to a practically complete extinction of all rays by widespread absorption in the upper atmosphere.

The only weapon against this sort of fading is the alteration of wavelength to suit conditions, but, so far, this has not met with much success, for this type of fading seems to be prevalent on all waves in the short wave band, say 14 to 50, and the results obtained seem a little contradictory.

From our own experience it would appear that this type of attenuation (rather than fading) chiefly affects the Canadian and American circuits, and that the 15 to 16 metre wave band is not much less affected than the 26M. band.

This was particularly marked on the occasion of the storm on April 14th, when Canada on 26M. and the American short wave stations 2XBC 14M., 2XS 15M., 2XT 10M., and WLL were unheard all day until about 1610, and when CG and all the short wave American Stations appeared between 1545 and 1625.

Picard, in Proc. I.R.E., February, 1927, has shown that a very strong correlation exists between magnetic character and short wave signal fading; a correlation

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factor as great as — 0·89 to 0·06 being obtained in transmissions between Chicago and Boston on a 22·5 metre wave early in 1926.

Theory.

It is generally supposed that magnetic storms are caused by the incidence on the earth's upper atmosphere of streams of charged particles sent out from disturbed areas on the sun's surface. The disturbed areas are often associated with sunspots, but not invariably so. These magnetic disturbances have a tendency to repeat themselves in 27-28 day periods, *i.e.*, the rotation period of the sun on its axis relative to the earth, showing their dependence on a particular disturbed area of the sun's surface which is carried round in 27 days by the sun's rotation.

Examples of the recurrence of bad short wave fading after 27 day periods are exemplified in a period of fading on September 20th, followed by one on October 14th.

Again, a period on March 16th, 17th, 18th, followed by another on April 11th, 12th, 13th, 14th.

On the other hand, it is impossible to predict any recurrence, for a given disturbance on the sun's surface may have died out during the 27 day period of rotation.

Magnetic observations indicate an increased conductivity of the Heaviside layer during the times of magnetic disturbance, caused no doubt by either the direct increase of the number of ions, or indirectly by their ionisation effect. (Increased reflection coefficient on long waves.)

Such an increase in ionisation, if the generally assumed theory of short wave transmission is correct, will result in increased attenuation. The attenuation is proportional to $N\lambda^2$ where N is the number of ions per cc., and an increase of N will increase the attenuation for all short waves.

The bending of the ray is also proportional to $\frac{\lambda^2 dN}{dh}$, where h is the height; it therefore follows that if the density is increased at every point in the layer in a given ratio r, say, so that if the final and initial distribution of ions is similar, then the attenuation will be increased in the ratio $r\lambda^2$.

Thus, if r is increased four-fold everywhere, a two-fold reduction of λ will leave the attenuation and bending of the ray unaltered, and the transmission on half the original wavelength should be as good as before the increase of ionisation. Such an argument suggests that the use of sufficiently short waves might overcome this type of attenuation, but the actual facts do not give much support to this idea, and we must suppose that the original distribution of ions is altered by the eruption of ions from outside into the upper atmosphere. In the absence of any knowledge

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of how the ions are redistributed in the layer it is impossible to state what effect wavelength changes will produce. The general opinion is that no definite rule for choosing the wavelength so as to give the best results under disturbed conditions can be given in the present state of our knowledge.

There is just a possibility that a very short wavelength, say 5 to 10 metres, may be of use during these periods.

Fortunately, these effects are mostly confined to the Canadian and American circuits, the rays from which pass relatively close to the North magnetic pole.

Quick Fading.

The quick fading from periods of a minute or two to fractions of a second is of an entirely different nature, and it is characterised by the fact that while extinction may occur at one particular moment and place, a slight shift in position or frequency will bring the signals in strong again.

It is not a widespread fade in the sense that within a large band of frequencies all places are simultaneously robbed of energy, such as is the case with the magnetic storm fades just referred to, but is particular in respect of position and frequency.

In this respect there is hope of overcoming the fading by taking averages over a large band of frequencies or over large areas of space. Such a state of affairs can be most readily attributed to interference effects between two or more rays which for one particular frequency and place will interfere at one moment, and for neighbouring frequencies and positions at another moment. The irregular variation of the fading suggests a chance distribution, and one is led to consider the effect of the addition of a number of rays of random phase. These rays will sometimes add, and sometimes be in opposition, so that the resultant can be expressed as a function of the time of irregular varying amplitude. From the point of view of fading, the significant quantity is the variability of this curve. There is a mathematical method of assigning a number to this quantity, which can be explained as follows: Let the actual curve be represented in the figure:

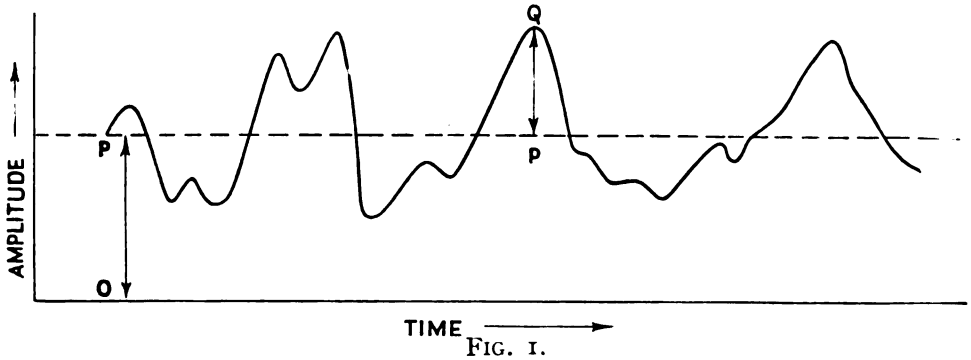

FIG. 1.

and let OP be the mean ordinate over a period which includes many peaks and valleys of the curve.

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Then if we take the difference between the ordinates of the curve and OP, *e.g.*, QP and square them, and take the mean, we shall have a measure of the variability.

This quantity obviously vanishes when the ordinate is constant, and increases with the amplitude of the oscillations from the mean, and is therefore a good measure of the variability. It is possible to calculate what this variability should be on varying assumptions, including, of course, that in which it is considered as a statistical problem in which the phases of the component rays can be considered to be on the average chosen at random. Fading of this sort may be due to the interference of two or more rays, and the variability will be a function of the number of rays interfering.

Thus, we should expect that with a large number, N, of rays, the probability that all the phases should be arranged so that the resultant is zero, or N will be very small, whereas in the case of two rays this probability is relatively large, and we should therefore expect a much larger variability in the latter case than in the former.

But it is important to have actual figures so that we can determine of the actual fading, whether it is of the many ray type or of the few ray type.

In calculating the variability in the case of two rays, we may assume from physical considerations, and the fact that at times they practically completely cancel each other, that they are both of the same average intensity, E, say.

The resultant r of the two will then be :

$$r^2 = 2E^2(1 - \cos\theta) \quad . \quad . \quad . \quad . \quad (1)$$

where θ is the phase angle between the two.

The probability that θ lies between θ and $\theta + d\theta$ is $\frac{d\theta}{2\pi}$, so that the probability that r lies between r and $r + dr$ is $\frac{d\theta}{2\pi\, dr} \cdot dr$

$$2r\,dr = 2E^2 \sin\theta\, d\theta \text{ (from (1))}$$

$$\frac{dr}{d\theta} = \frac{E^2 \sin\theta}{r}$$

$$\frac{1}{2\pi}\frac{d\theta\, dr}{dr} = \frac{1}{2\pi}\frac{r\, dr}{E^2 \sin\theta}$$

$$\text{Now } \cos^2\theta = 1 - \frac{r^2}{E^2} + \frac{r^4}{4E^4} \text{ from (1)}$$

$$1 - \cos^2\theta = 1 - \left(1 - \frac{r^2}{E^2} + \frac{\frac{r^4}{4E^4}}{2}\right) = \frac{r^2}{E^2}\left(1 - \frac{r^2}{4E^2}\right)$$

$$\sin\theta = \frac{r}{E} \cdot \sqrt{\left(1 - \frac{r^2}{4E^2}\right)}$$

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$$\frac{1}{2\pi}\frac{d\theta}{dr}\cdot dr = \frac{1}{2\pi}\cdot\frac{dr}{E\sqrt{1-\frac{r^2}{4E^2}}}$$

and the probability that r lies between O and 2E

$$= \frac{2}{2\pi}\int_0^2 \frac{dz}{\sqrt{1-\frac{z^2}{4}}} = 1,$$

as it should be.

The variability can now be calculated as follows:—

In the first place we have to calculate the mean square value. It is

$$\frac{2}{2\pi E}\int_0^{2E}\frac{r^2 dr}{E\sqrt{1-\frac{r^2}{4E^2}}} = 2E^2$$

and the mean square deviation or variability is

$$\frac{1}{\pi E}\int_0^{2E}\frac{(r-\sqrt{2}E)^2\,dr}{E^2\sqrt{1-\frac{r^2}{4E^2}}} = 4E^2\left(1-\frac{2\sqrt{2}}{\pi}\right)$$

and the ratio of this to the average value is

$$2\left(1-2\sqrt{\frac{2}{\pi}}\right) = 0.200$$

Application of Probability Theory.

In the case where n, the number of rays, is large, we can use the results given by Lord Rayleigh (*Theory of Sound*), where he shows that the probability that the resultant r of n vectors of random phase lies between r and r + dr is

$$\frac{2}{n}e^{-r^2/n}\cdot r\,dr$$

The mean square amplitude is

$$r_1 = \frac{2}{n}\int_0^\infty r^3 e^{-r^2/n}\cdot dr = n$$

so that the mean square deviation is

$$\frac{2}{n}\int_0^\infty e^{-r^2/n}\cdot r\,(r-\sqrt{n})^2\,dr$$

which can be shown to be $n(2-\sqrt{\pi})$, and the ratio to the mean square amplitude is therefore $(2-\sqrt{\pi}) = 0.228$.

Considering the two results together, we find that the percentage variability for two and for many rays is very nearly the same.

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The actual examination of observed fading curves, an example of which is given here, shows that the variability is much greater than can be expected from the random interference of either few or many vectors, and even were the vectors of different amplitude the expected variation would be less.

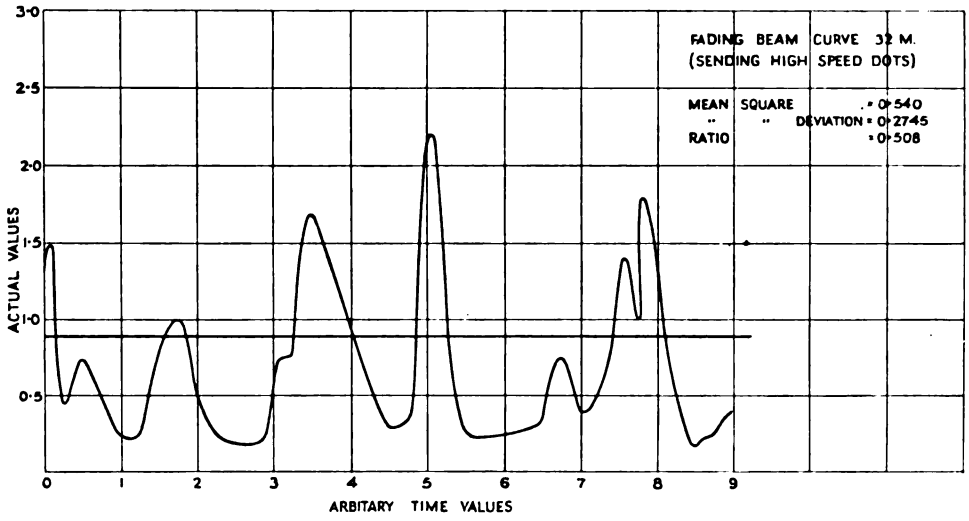

FIG. 2.

The pronounced peakiness of the fading curves on these lines seems very difficult to explain.

Under scattering conditions the signals appear to be much steadier, and the variability probably approaches the theoretical value 0·228 fairly closely.

The reason for this is obvious if we consider the nature of scattered radiation, which consists of a large number of rays (*approximately of equal amplitude*) and of random phase.

(*To be Continued*)

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MARCONI NEWS AND NOTES

THE MARCONI SHORT WAVE BEAM SYSTEM

While other pages of this Review will deal with scientific and technical problems and developments of wireless communication, this section will be devoted each month to a review of the commercial activities of the Marconi Company and the uses which are being made of its manufactures in carrying out wireless communication in all its forms in all parts of the world.

NO subject can be more appropriate for the first place in this series of notes than the astounding success that has followed the development of the Marconi Short Wave Beam System.

There are four groups of Beam services at present in operation :—

(1) The Beam stations built by the Marconi Company in England, for the General Post Office, for direct high-speed communication with the British Dominions and India ; with corresponding Beam stations in the Dominions and India.

(2) The Marconi Company's own group of Beam stations for communication "Via Marconi" with the United States of America, the Argentine, Brazil, Egypt and the Far East.

(3) The Beam stations built by the Marconi Company for the Companhia Portugueza Radio Marconi for communication with Brazil, Angola, Mozambique and the Cape Verde Islands.

(4) Marconi Beam stations purchased by other non-British countries for long distance wireless communication.

All these Beam services have attracted to themselves large volumes of traffic as soon as they have been put into operation, and the amount of traffic handled and the speed of transmission and reception has definitely established the Marconi Short Wave Beam system as the most efficient means of high-speed long distance wireless telegraph communication for the future.

The efficiency of this system is shown by the fact that the amount of traffic carried by the service between England and Australia has already grown to a figure approximating 9,000,000 words per annum ; while the traffic on the whole of the British Imperial services has been steadily growing at an average increase of approximately 3 per cent. per week, the total now standing at the substantial figure of over 40,000,000 words per annum.

The flexibility and carrying capacity of the Marconi Beam services is shown by the fact that, though they are normally worked at between 100 and 200 words per minute, much greater speeds are attainable, and 400 words per minute have been worked on commercial traffic during periods of pressure.

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There are at present 26 Marconi Short Wave Beam stations in operation in :—

ENGLAND	CANADA	AUSTRALIA
SOUTH AFRICA	INDIA	EGYPT
PORTUGAL	MOZAMBIQUE (Portuguese E. Africa)	ANGOLA (Portuguese W. Africa)

and other countries.

It may be considered by some observers that the directional properties of the Beam limit the usefulness of this system, but there is little in this argument, as is shown by the flexibility of existing Beam stations and the fact that—

1. The width of the Beam may be varied by utilising one or more bays of the aerial system.
2. It is possible, while keeping the Beam at any desired width, to swing it, with but small loss of efficiency, over a small arc, by a few alterations in the circuit and without any structural alterations to masts or aerials. Thus, one set of masts may be used for one service on one side and for another service at an angle to the great circle bearing for which the masts are primarily aligned on the other side.

With the growing number of short wave stations now being established and the consequent possibility of congestion in the future, the value of the Beam will become increasingly evident as a means of avoiding interference from and with other stations.

Marconi Beam Station at Dorchester with Seven Transmitters.

The directional properties of the Beam also play an important part in the elimination of atmospheric interference ; and the reflector not only tends to eliminate atmospherics from behind the station, but also interference due to echo, *i.e.*, waves which travel round the world in the opposite direction from the main signal.

Whenever an invention of a revolutionary character has been made, rival inventors, in order not entirely to be out of the picture, have suggested some modification in the detail of the application of the invention, and have made the claim on behalf of their modification that it has advantages over the original idea. It is not, therefore, surprising, and indeed it was inevitable that, following on the sensa-

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tional success of Senatore Marconi's Beam system, other wireless inventors should have seized on his central idea, and, by modifying certain details of it, should endeavour to show that the Marconi Beam system is not the only directional system of wireless telegraphy. Even rivals have to admit, however, that the system they are putting forward is the Marconi Beam system with certain alterations in detail. The essential idea of these rival systems is the essential idea of the Marconi Beam system. All that the competitors have done, all that they claim to have done, is to have made certain small changes in the form of application of Senatore Marconi's invention.

The Marconi Beam system, however, is the only one which has been tried in commercial practice for any sufficient period of time. It is working over the greatest distance and under the most varied conditions, and it is carrying a larger volume of traffic than any other telegraph circuit in the world.

The Marconi technical staff have this advantage over the technical staffs of other wireless companies, that they have been able to observe the system in actual commercial working for two years, and no one supposes that they have been standing idle. It can be taken for granted that every claim which has been made by other inventors has already been anticipated by the Marconi technical staff, and that in regard to price, size of aerials and carrying capacity, the Marconi Company's system is at least two years ahead of any other.

It has been proved by the experiments carried out by the Marconi Company's engineers, that, whatever may be said to the contrary, a Marconi Beam aerial system gives better results than can be obtained by any of the various modifications of that system which are being put forward by competitors.

Marconi Aircraft Wireless.

No wireless company in any part of the world has had as much experience of wireless for aircraft as the Marconi Company.

As early as 1912 the Marconi Company, which had already achieved outstanding success in other branches of wireless communication, began to devote serious attention to wireless communication for aircraft, and it was the first to design and manufacture a practical wireless set for use in aircraft.

It has maintained this ascendancy in all types of aircraft wireless apparatus for both civil and military purposes, as is shown by the fact that it is also used for Service or Commercial purposes in the following countries :—

Great Britain and British Dominions.

Argentine.	Czecho-Slovakia.	Italy.	Portugal.	Sweden.
Belgium.	Denmark.	Japan.	Roumania.	Switzerland.
Brazil.	Greece.	Mexico.	Russia.	U.S.A.
Chili.	Holland.	Persia.	Siam.	Uruguay.
China.	Hungary.	Poland.	Spain.	Yugo-Slavia.
Colombia.	Iraq.			

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The London Air Port at Croydon has the most up-to-date and the most efficiently administered aerodrome wireless ground station in the world. It was built for the British Air Ministry by Marconi's Wireless Telegraph Company, and in its construction were combined the results of the experience and technical knowledge of the British Air Ministry and of the Marconi Company.

Marconi A.D.6h Aircraft Wireless Set.

Marconi apparatus is the standard equipment for all British Civil aircraft, and its reliability and value to aerial navigation is shown by the regularity of the journeys made by Imperial Airways machines in all weathers.

Pioneer Flights.

Apart from its use in established air routes, Marconi wireless equipment has also a fine record of service in connection with pioneer flights, where its value for navigation and in maintaining communication with the outside world has been incalculable.

The Company's long experience has, of course, given it unrivalled knowledge of the requirements of such ventures, and it is the only company which has had experience of fitting wireless direction finders to all-metal flying boats such as those used by the Spanish airman Commander Franco on his flight to South America, and Captain Courtney, the English airman, on his attempt to fly across the Atlantic.

Discussing the technical lessons and experience of his flight, Commander Franco says :—

> " Wireless telegraphy has assisted us in such a manner that in future it should be considered indispensable for flights over sea or deserted land."

Captain Courtney, brought down at night after flying 700 miles of the journey from the Azores to Newfoundland, was able to determine his position by means of his direction finder, and after his rescue immediately sent the following telegram to the Marconi Company :—

> " Rescue entirely due to Marconi wireless."

The " Aeroplane," one of the leading English aeronautical periodicals says :—

> " The outstanding feature of the rescue of Mr. Courtney and the crew of the Dornier Wal was certainly the faultless functioning of the Marconi wireless apparatus."

If the flight had been successful a great deal of the credit would have been due to the Marconi wireless apparatus, which was in constant use in the earlier stages of the flight in sending messages and in taking wireless bearings.

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No. 2

THE MARCONI REVIEW

November, 1928

CONTENTS

A CHAPTER IN THE HISTORY OF THE MARCONI BEAM—II - - - - - - - PAGE 1

THE BRATISLAVA BROADCAST TRANSMITTER. TYPE P.A.5 - - - - - - - „ 11

DISCUSSION ON SHORT WAVE FADING—II - „ 18

LONG WAVE SHIELDED VALVE NAVAL RECEIVERS TYPES R.G.18 & 19 - - „ 24

MARCONI NEWS AND NOTES—
START POINT WIRELESS BEACON - - „ 31

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD.

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THE MARCONI REVIEW

No. 2. *November, 1928.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

A CHAPTER IN THE HISTORY OF THE MARCONI BEAM—II.

In Part I. of this article the position of affairs prior to the advent of the Marconi Beam system of communication was briefly reviewed and an account was given of the successful range trials of the experimental Short Wave Reflector plant at Poldhu carried out by Senatore Marconi on board the S.Y. "Elettra" in 1923-24.

The British Government contract for the construction of the Imperial Beam Stations followed. Since then the Marconi Beam system has definitely proved itself to be of immense value for Imperial communications.

The technical advances made in Short Wave Reflector transmission and reception up to the date of the signing of the contract were also described.

In Part II. of this article, given below, the further technical advances made up to the date of the opening of the first Imperial Beam Station are described, criticisms of the Marconi Beam system are discussed, and it is shown that certain suggestions which have been made for cheapening the standard Beam station equipment result in a loss of technical efficiency.

The Receivers.

THERE were two receivers, designed by Mr. Mathieu, in use on the "Elettra." The first of these, a copper-screened two-valve instrument, having a waverange of 40 to 100 metres, was used for signal intensity tests, and employed, as shown in the circuit diagram, Fig. 5, an aperiodic aerial, a detector valve with reaction, a tuned grid circuit with vernier condenser, a low pass filter to isolate the telephone circuit from reaction effects, a low-frequency transformer and an audibility test circuit to which the telephone was connected. The test circuit consisted of an artificial line graduated in standard miles and providing a range of adjustment equivalent to 0 to 100 T.U.

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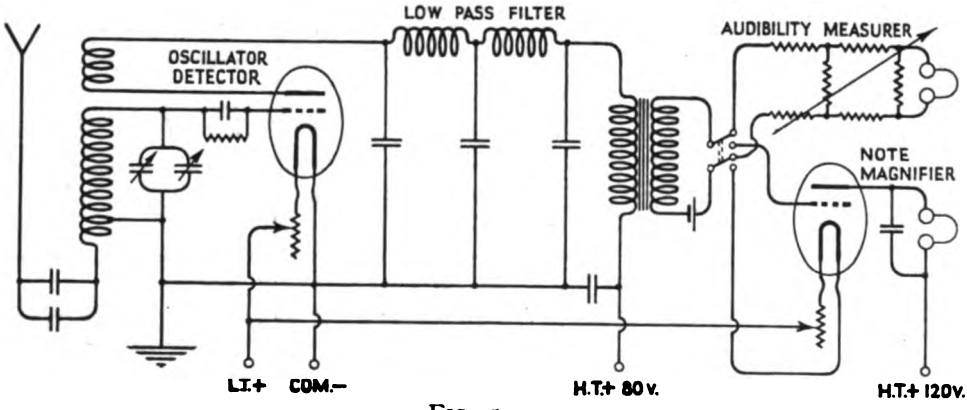

FIG. 5.

For normal reception the artificial line was switched off and an amplifying valve was used.

The second receiver was used to determine the type of instrument best suited for short wave traffic service, and comprised an aerial circuit, tuned intermediate circuit, a frequency changer circuit, two stages of sharply tuned high frequency amplification, and an autoheterodyne detecting valve, to which could be added two stages of low frequency amplification.

It was shown that sharp tuning would not do. To allow for wavelength wobble, filter circuits, suitable for passing narrow bands of frequency, and giving flat topped tuning, were required.

The Function of the S.Y. "Elettra."

A moving station possesses a great advantage over a fixed one whenever propagation problems are at issue.

If the transmission characteristics of the medium are unknown, a communication test between two or more fixed points will give data which can be used for the design of other stations at the same distance apart, but if one of them is mobile, the data collected can be expressed as an empirical law applicable to the design of stations at all intermediate distances, and within reasonable limits, to distances greater than that between the terminal stations.

Thus, the well-known Austin-Cohen formula for long wave propagation was deduced from the results of tests carried out between cruisers of the United States Navy and Brant Rock, and provided a reliable basis for long wave transmission calculations within known limits, and the tests between the "Elettra" and Poldhu had a similar character, as a very complete check was obtained, not only on signal

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strengths, but also on the width of the beam at different distances from Poldhu, and by providing many points on the distance-intensity curve removed the last vestige of doubt as to the effectiveness of the Beam at a distance.

By employing the "Elettra" the period of preliminary research necessary before a considered opinion could be given on the possibilities of the beam for world communications was shortened considerably, as a probability was turned into a certainty, and Senatore Marconi was therefore able to speak with absolute confidence of the future success of the system, which would not have been possible at this early date if the tests had been limited to communications between fixed stations.

The Long Wave Station at Rugby.

At this early stage of development, while no doubt remained that some sort of communication could be effected, the British Post Office could not be expected to be so optimistic as the Marconi Company about the commercial success of the Beam, and the construction of the high power long wave station at Rugby was therefore still proceeded with, its strategic value as a Broadcast Station being considered to be of first importance.

If the Beam stations were not successful, the risk was entirely that of the Marconi Company, and Great Britain would endeavour to send all her traffic by long wave; if they were successful, the Post Office would benefit, and the Beam service could be used to supplement the 24 hours' service which Rugby was expected to give.

Opinion, however, was otherwise in the Dominions; work on the high power long wave stations ceased, and, as a result of negotiations with the various Governments, the Marconi Company put in hand Beam stations for Canada, South Africa, Australia and India.

Continuation of Range Trials.

The range trials from Poldhu to the "Elettra" and to the listening posts all over the world were renewed in August, 1924, this time with the object of noting the effect of employing shorter wavelengths, transmission taking place on 15 kw. and with the aerial system and high frequency circuits altered from 92 metres to 60 metres, then to 47 metres, and finally to 32 metres, when, for the first time, it was definitely discovered that the daylight range increased very rapidly as the wavelength was reduced: New York, Rio and Buenos Ayres were finally able to receive when both terminal stations were in daylight; and Sydney, N.S.W., reported being able to read signals for 23½ hours out of the 24.

And so already research had revealed further useful features in short wave propagation, and had strengthened the confidence of the Marconi Company in the successful outcome of the Beam contract.

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This concluded the preliminary transmission programme between Poldhu and the S.Y. "Elettra."

The research on short waves was continued at Chelmsford, and in October, 1925, using a plain half-wave aerial without reflector, it was found that a 15-metre wave, with only 200 watts to the aerial, was sufficient to give strong commercial signals at Buenos Ayres with the sun at its zenith on the great circle track, and before the first station was opened the Marconi Company had accumulated sufficient data by the aid of long distance tests to be able to determine the daylight absorption factor of all short wavelengths from 100 metres down to 10 metres, in addition to much information obtained by short distance tests of the behaviour of wavelengths from 15 metres down to 2 metres.

The actual dates when the Imperial Beam Stations were opened for service after completing their acceptance trials, were as follows :—

Transmitting Station.	Call Sign.	Wavelengths in Metres.	Receiving Station.	Date Service Opened.
Bodmin (England)	GBK	16·574 32·397	Yamachiche ... (Canada)	25th Oct., 1926.
Bodmin (England)	GBJ	16·146 34·013	Milnerton ... (South Africa)	5th July, 1927.
Grimsby (England) ...	GBH	25·906	Rockbank ... (Australia)	8th April, 1927.
Grimsby (England) ...	GBI	16·216 34·168	Dhond ... (India)	6th Sept., 1927.
Drummondville (Canada) ...	CG	16·501 32·128	Bridgwater ... (England)	25th Oct., 1926.
Drummondville (Canada) ...	CF	24·793	Rockbank ... (Australia)	16th June, 1928.
Klipheuval (South Africa)...	VNB	16·007 33·708	Bridgwater ... (England)	5th July, 1927.
Ballan (Australia)	VIZ	25·728	Skegness ... (England)	8th April, 1927.
Ballan (Australia)	VYZ	24·958 16·286	Yamachiche ... (Canada)	16th June, 1928.
Kirkee (India)	VWZ	34·483	Skegness ... (England)	6th Sept., 1927.

The Beam Service with Canada was to have been opened within six months after the sites of the transmitting and receiving stations had been chosen by the Post Office, but it was actually twelve months before this took place.

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Research, development and erection work progressed together, the magnitude of the undertaking becoming more apparent as the practical details of design were worked out. The Post Office engineers being aware of the facts, agreed to the extension of the time limit as regrettable, but necessary and inevitable.

Later Progress.

The developments which occurred from the date when the contract was signed to the opening of the first Beam channel were as follows :—

The aerial was given its present design of a vertical sheet of separate aerials, each with its own feed. Phasing condensers then gave place to spiral phasing coils, and now, in order to reduce the reflection along the aerial wires which took place at these coils, they are made up in their present zig-zag form.

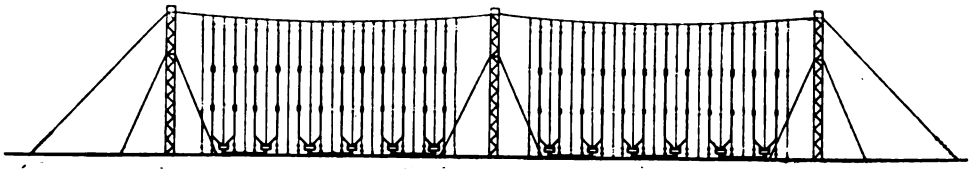

FIG. 6.

In the sketch elevation, Fig. 6, the terminals of the feeder system are shown connected to the bottom ends of the aerial wires, while the wires of the reflector, which are twice as numerous as those in the aerial, are shown in between.

The contract called for a 30° beam. The design of the Imperial Stations aerial systems provided a beam having a divergence of about 11°. Thus a very large increase in intensity was obtained above that originally proposed.

The parallel wire feeders became concentric air-spaced copper tubes fitted with expansion joints, the outer one earthed and the inner one making suitable tapping connections to screened transformers wherever a branch connection was required, and the length of the feeders to the individual aerials had to be compensated to make them all electrically equivalent.

As the best wavelength for each particular service had yet to be determined, the design of the transmitter was made as flexible as possible. The power to the anode of the magnifier was 20 kw., as used in the later " Elettra " tests, but instead of this circuit being controlled by a 6 kw. drive employing several valves in parallel, the set was made more stable, and the constancy of the wavelength brought better under control by reducing the drive power to about 100 watts, and employing one valve, three stages of magnification being then used instead of one, the circuits being of the balanced push-pull type, with single valves in each arm.

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Crystal drives and tuning-fork drives were in use at that date, but they were not capable of frequency adjustment, and so a standard type of self-oscillator circuit was employed.

The wisdom of this has often since been demonstrated. Small, and sometimes large changes of wavelength were occasionally required in the preliminary tests, and the adaptability of the transmitter was a useful asset.

Originally designed to be adjustable to any wavelength found necessary from 60 metres to 20 metres, the transmitter was finally altered to cover the present waverange of 40 metres to 15 metres. The method of keying at Poldhu was by wave-change. To economise frequencies, the absorber valve method was introduced at the Imperial Stations.

The systematic transmission tests from Poldhu to various parts of the British Empire brought to light sufficient data to show that the best wavelength for a given channel depended not only on the position of the sun relative to the great circle through the communicating stations, but also on the distance and on the season of the year. Wavelengths of 20 to 30 metres are usually best suited for night transmission, and wavelengths of about 15 metres for daylight transmission. Every change of wavelength at the transmitter necessitated a change in the length of the aerial and reflector wires and phasing coils and a readjustment of the feeder circuit, and owing to the increase in the number of wires with smaller spacing which was employed with the shorter wavelengths, the large factor of safety which had been allowed for in the loading of the special self-supporting cantilever masts at the Imperial Stations was found to have been a useful safeguard.

The Marconi Short Wave Beam Receiver.

The reliability of a commercial service demands that the aerial shall pick up a strong signal, and this is provided at all the Beam receiving stations. This ensures that during the short fade periods the strength of the signal fluctuates, but is still considerable at its minimum value. The receiver then takes this signal and amplifies it, so that the maximum speed of working can be obtained at the trough of the short fade periods, and as the peaks of the signal currents do not enable the speed of working to be improved, they are therefore reduced by limiting circuits. The general scheme of the Marconi Beam receiver is shown in Fig. 7.

Short fading is less pronounced in a Marconi Beam service than a broadcast aerial service. This was to be expected if the assumption usually made is correct, that fading is due to the interference of rays which leave the transmitter at different zenithal angles, as any concentration in the vertical plane must reduce the inter-

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ference possible when the rays which travel into the upper atmosphere are bent down again, and also there is less high angle radiation.

Short fading was also found to be supplemented periodically by complete fading at times of sunspot activity, when the great circles through the stations pass through or near the polar regions, this complete fading corresponding to magnetic storm disturbances experienced at the same time on the cables. Low latitude communications and long wave channels are much less subject to interruptions from this cause.

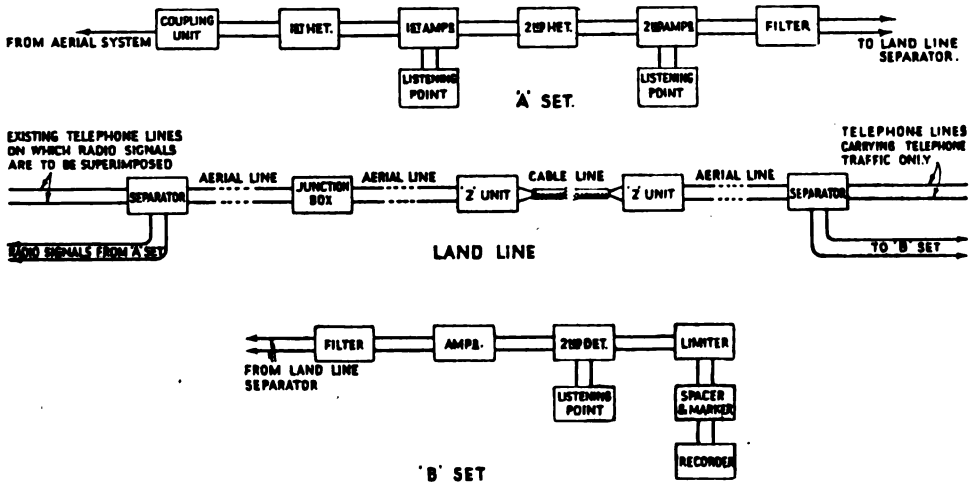

FIG. 7.

Interest Abroad in Progress of Beam System.

Competitors of the Marconi Company abroad had been watching with considerable interest, but some business scepticism, the progress, first of the Beam researches, and, later, the development of the Beam stations, under the impression that they were about to witness a scientific experiment carried out on a very large scale, but one which involved so many unknown and variable factors that commercial success was very doubtful.

The unexpected, however, happened, and they awoke to the sudden realisation that not only was a world-wide Beam network in being and doing profitable business, but the future of radio communications was bound up with the extended development of the Beam principle, and they were years behind the Marconi Company in the new technique.

Broadcast traffic transmission was wasteful, and limited the number of possible channels, and for ultra short waves, to which attention is now being directed, the

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dimensions of aerials and reflectors are so much smaller that the factor of cost is no longer a formidable item.

These firms have therefore now entered this field of development, and have devised beam aerial systems which copy in principle the Marconi-Franklin model, but differ from this model in certain important technical features, which it is claimed allow the cost to be considerably reduced.

It will be instructive to examine some of these methods for producing a cheaper short wave beam, as they also result in a sacrifice of technical efficiency.

At first arguments were brought forward to discount the value of directive radiation. Critics of the Beam system contended that as energy tends to an average throughout the radiated wave, so that inequalities in the wavefront fill up, the beam as it travels further would become more diffuse, so that at a great distance it would show no concentration, and that the action of the refracting layers would certainly encourage this.

There were some tests also made in Germany with a horizontal reflector, which appeared to confirm this view until further information came to hand which explained the results, for it was found that the dimensions of the reflector relative to the aerial were such that the radiation propagated was widely dispersed at the source, at no time did it possess true beam concentration, and the zenithal angle at which the main radiation left the aerial was very different to what had been assumed.

The results of a long series of careful direction finding tests go to show that vertically polarised radiation leaves the Marconi-Franklin Aerial Reflector system inclined at a zenithal angle of about 15° to the horizontal, that within the region of the skip distance the radiation is mainly passing overhead in the Heaviside layer, but below this layer it is scattered ; also that beyond the skip region the radiation once more attains a directional character giving a great circle bearing, and strikes the receiving aerial at a small zenithal angle.

Strong Signals Required for High Speed Working.

The next argument was that aerials and reflectors were larger than was actually required.

We have learnt that very little power is necessary to reach to the ends of the earth on a suitable short wave, but that to work at high speed requires strong signals.

While it was possible to communicate at under 50 words a minute from Germany to South America, and also from France to West Africa and South America with types of beam aerial having much less area than used at the Imperial Beam Stations, on account of which a saving in cost was claimed, these smaller aerials denoted that

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the beams produced had a wider spread of radiation, which resulted in weaker signals at the receiver and a slower speed of working.

There is no service anywhere in the world which can work at so high a speed as the Marconi Beam Stations, a record which has not been approached since they were opened two years ago, and it is interesting to note that our competitors, in order to obtain signals of the requisite strength and dependability for commercial service, are now increasing the area of their aerials to approach nearer to the standard which the Marconi Company established when the Imperial Beam Stations were erected.

The separate feed to each vertical wire of the Franklin aerial is elaborate but very efficient, and where cost must be considered, it is natural to enquire whether a simplified and cheaper system could not be devised.

Suppose the aerial wires were fed from the transmitter in groups instead of individually, what would be the result ?

The feeder itself would cost less, but the aerial would cost more, as in order to obtain an even distribution of current throughout the network, the aerial end would have to be complicated by the addition of a special phasing unit in each wire of the group, having a value graduated to the distance from the feeding point. Also, as the adjustment of these phasing units is correct for one frequency only, any slight change in wavelength would immediately upset the balance of current throughout the aerial, and the concentration of the beam would alter.

If phasing units were not employed, the radiation would be so diffuse that, although it would have direction, it could no longer be described as a beam.

Types of Projector Aerials.

In recent American and French designs of projector aerials, rectangular and lozenge-shaped networks have been employed, which are broken up by insulators so as to constitute several groups of half-wave aerials in series, suspended one above the other, and these groups are fed either from one end or from the middle.

A cheaper feeder system is in consequence obtained, but the character of the beam is again adversely affected.

The current in the network, instead of being evenly distributed, is greatest near the feeding point ; if this is at the end the beam will not be at right angles to the plane of the aerial, if it is at the middle, the direction will be correct, but the beam will have a wide angle, and in both cases any slight change in the frequency of the transmitter will cause the beam to swing away from the correct direction.

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The Franklin method of feeding the aerial does not introduce this trouble ; if the frequency alters, the intensity of the beam is affected, but its direction and concentration do not change, so that the cost of the feeder system is fully justified.

It has been asked whether the success of the Beam system, as such, is mainly due to the good qualities of the transmitter, the efficiency of the transmitting aerial and reflector as a beam producer, the effectiveness of the aerial and reflector at the receiving end as a collector of energy over a wide area, or to the excellence of the receiver.

Would it be possible, for instance, to replace any part of the installation with something less elaborate and cheaper, and still get very nearly the same result ?

The reply is, that each section of the system contributes a substantial quota to the total.

The system was developed as a whole, and if only part of the equipment were used the efficiency of the complete design would disappear, and any reduction in first cost would soon be more than offset by the fall in the traffic returns due to a less reliable service and a slower speed of working.

Present Position of Imperial Beam Services.

The Cable and Wireless services of Great Britain and the Dominions are now at the point of merging their interests.

With a common centre for Imperial and foreign communications at the heart of the Empire, the creative energy of the new composite organisation which is being formed, can be devoted without stint to the actual business of traffic expansion along existing channels, and to the economic development of new channels ; the stimulus of foreign competition ensuring that nothing less than the best and most up-to-date equipment will survive and be employed in the operation of these public world communication services.

H.M.D.

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A DESCRIPTION OF THE BRATISLAVA BROADCAST TRANSMITTER

MARCONI TYPE P.A.5

Czecho Slovakia occupies a very favourable position for broadcasting in the heart of Europe. The area of the Republic is about 150,000 sq. kilometres and is therefore roughly as large as Great Britain. Its population, which includes several distinct races, is approximately fourteen millions.

The first steps towards broadcasting in Czecho Slovakia were taken in 1923 and since then rapid strides have been made towards a well organised and efficient broadcasting service.

When all the projected stations are completed, Czecho Slovakia will be entirely independent as regards the transmission of Central European news to its own nationals, it will be in a position to broadcast in the best manner possible to overcome the language difficulty, and its own news will be more widely distributed to foreign countries.

Of the chain of five stations projected to complete the Czecho Slovakian Broadcasting Organisation, the new high power station to be erected shortly at Bratislava, situated on the Danube and the Austrian border, will be the largest and will function in very much the same way as Daventry does in Great Britain.

A description of the Bratislava transmitter which illustrates a new departure in design is given below.

THE transmitter to be described below is one of a series developed by the Marconi Company with a view to providing broadcast transmissions of high quality and conforming in every respect to the technical requirements of modern practice.

The simpler types of transmitters consisting of a modulated self oscillator, or a drive and single magnifier, although having given, and in fact continuing to give excellent service, are not now considered quite adequate in certain respects, and more complicated sets are called for to cope with present day conditions.

In the design under review particular attention has been given to the following points :—

(A) Great constancy of wavelength independently of the regulation of the supply mains.

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(B) Complete freedom from any frequency change of the carrier wave due to modulation.

(C) Deep modulation without distortion.

(D) A straight line frequency characteristic throughout the useful audio-range.

(E) Freedom from harmonic radiation.

(F) Adjustability to any wavelength within the authorised broadcast band (200-545 metres, 1,500 to 550 K.C.).

(G) Compactness, together with adaptability to various lay-out arrangements, in order to suit differences in shape and size of the accommodation space.

The particular set to be described has been ordered from the Marconi Company by the Broadcasting Organisation of Czecho Slovakia and will be erected at Bratislava to replace the small power transmitter at present serving the locality. The wave-length allotted is 300 m. This transmitter is rated at 12 kw. carrier energy, and is designed for linear modulation up to 80 per cent., so that at full modulation the aerial power amounts to 15.8 kw.

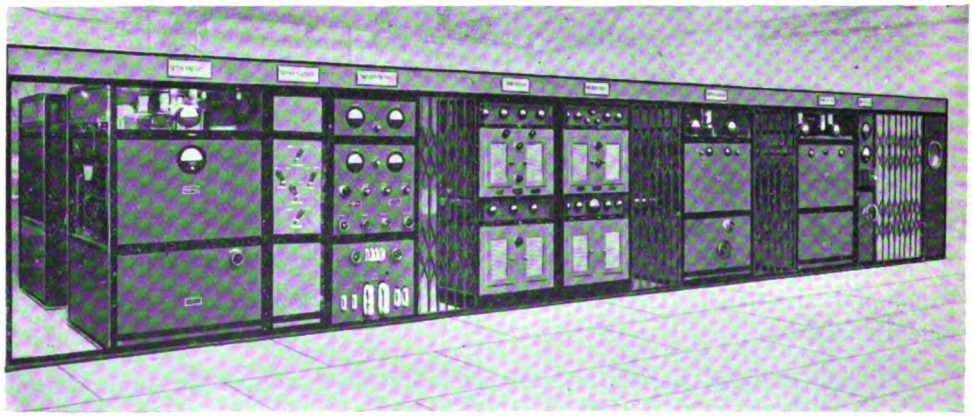

FIG. 1.

The transmitter proper (Fig. 1) comprises seven independent units, namely :—

1. Drive Unit.
2. Modulated Amplifier Unit.

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3. Intermediate Amplifier Unit.
4. Power Amplifier Unit.
5. High Frequency Unit.
6. Harmonic Filter Unit.
7. Feeder-Aerial Coupling Unit.

A description of these units in detail will enable a clear idea of the design to be obtained.

1.—The Drive Unit.

This consists of two completely shielded stages, the drive and the isolator, each complete with high frequency circuits and mounted in one framework. The drive uses two valves, Type DET. 1, the filaments of which are supplied from an accumulator battery, and the anode voltage is provided by a one thousand volts motor generator driven by the same accumulator.

This arrangement renders the drive frequency completely independent of any fluctuations in the power mains, and makes possible a very high degree of constancy. Any wavelength between 200 and 545 metres is available by adjustment of the tuning condensers and inductances. The drive is inductively coupled to the isolator by variable coupling coils tuned by a variable condenser.

The valve used for the isolator is one T. 250A, which takes its filament supply from the main filament lighting D.C. dynamo. The anode voltage for this valve comes from the 3,000 v. machine, which also feeds the modulated amplifier unit.

The isolator circuit is neutralized, and the valve is provided with a negative bias so adjusted that no grid current flows, in order that the load on the drive shall remain constant.

The isolator is directly coupled to the succeeding stage (Modulated Amplifier) by means of a variable tapping on the anode tuning coil.

2.—The Modulated Amplifier Unit.

This unit consists of two shielded stages mounted in one framework of similar dimensions to the Drive Unit. One case mounts the modulated amplifier with its high frequency oscillatory circuit, and the other the modulator and sub-modulator together with the speech choke, coupling resistances, etc.

The valve used for the modulated amplifier is one DET. 3 with D.C. machine filament lighting. The working anode voltage is approximately 1,250 volts, the 3,000 volt supply being reduced by a resistance shunted by a large condenser to bye-pass the audio-frequency component.

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The circuit is neutralized and negative grid bias is provided by a condenser and leak resistance.

The anode supply is connected through an iron cored choke coil for purposes of modulation.

The modulated amplifier is inductively coupled to the succeeding stage (Intermediate Amplifier) by variable coupling coils connecting with a tuned circuit.

The modulator valve is one MT9L and the sub-modulator one DET. 2. Both valves are fed from the 3,000 volt D.C. supply, although in the case of the latter this voltage is reduced by a series resistance. The filament of the MT9L is lit from the D.C. filament machine, and the DET. 2 from the accumulator of the drive stage. The modulator is resistance capacity coupled to the sub-modulator, and the sub-modulator is arranged for resistance-capacity coupling to the output line amplifier. The design of this stage is such that full (100 per cent.) modulation of the modulated amplifier is obtainable before grid current occurs in the modulator valve. The degree of modulation is registered by a modulation indicator, which consists of a milliammeter calibrated in kilovolts connected in series with a copper-oxide rectifier and a high resistance, placed across the speech choke.

3.—The Intermediate Amplifier Unit.

This unit forms a complete stage in one framework mounting one water cooled valve, Type CAM.1, together with its oscillatory circuit. The filament is supplied from the D.C. lighting machine, and the anode is fed from the main high tension supply at approximately 8,500 volts. A heavy negative bias is applied to the grid of this valve, and under normal conditions sufficient output is obtainable without the grid excursion producing grid current. The grid circuit is tuned and strongly damped, which serves two useful purposes, namely, prevention of sideband cut-off and stabilisation of the valve without the necessity of neutralizing the valve capacity. The intermediate amplifier is inductively coupled to the succeeding stage (Power Amplifier) by means of a tuned circuit.

4.—The Power Amplifier Unit.

This consists of three water cooled valves, Type CAT.6, connected in parallel. The cooling water is led to and from the valves through cooled rubber hose wrapped round the valve supports. As on the previous stage the grid circuit is tuned and damped by added resistances. A fixed negative bias is applied to the grids, but in this case the input voltage swings into grid current. Correct settings for coupling to the previous stage and adjustment of the anode tap are indicated by voltmeters which register the peak values of potential on both the grid and anodes. The same instruments also serve to indicate the degree of modulation.

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5.—The High Frequency Unit.

This comprises the variable tuning coils and condensers forming the oscillatory circuit of the power amplifier, all the components being completely shielded in a metal cabinet.

6.—The Harmonic Filter Unit.

This is a low-pass filter combination formed of fixed inductances and condensers mounted in shielding boxes, designed to cut off all harmonic frequencies of the fundamental wavelength. The unit is intended to be connected directly on to a feeder line of 500 ohms impedance, and is coupled inductively to the tuning coil of the power amplifier oscillatory circuit. To prevent any direct action on the aerial from stray fields produced by the oscillating valves, which might nullify the effect of the filter in cutting out harmonics, a feeder of some 100 metres in length is inserted between the filter and the aerial circuit.

7.—The Feeder-Aerial Coupling Unit.

The inductances and condensers forming this unit are contained in a shielding cabinet, which will be housed in a small hut at the base of the aerial equidistant between the two masts. The feeder is inductively coupled to the tuning coils, and variable adjustments are provided so that the correct terminal conditions can be obtained. The components forming the unit can be arranged to be suitable for either a quarter or a half wave aerial, as may be found most effective by trial.

The aerial will be supported by two three hundred feet towers set about six hundred feet apart, and the usual buried earth system will be employed.

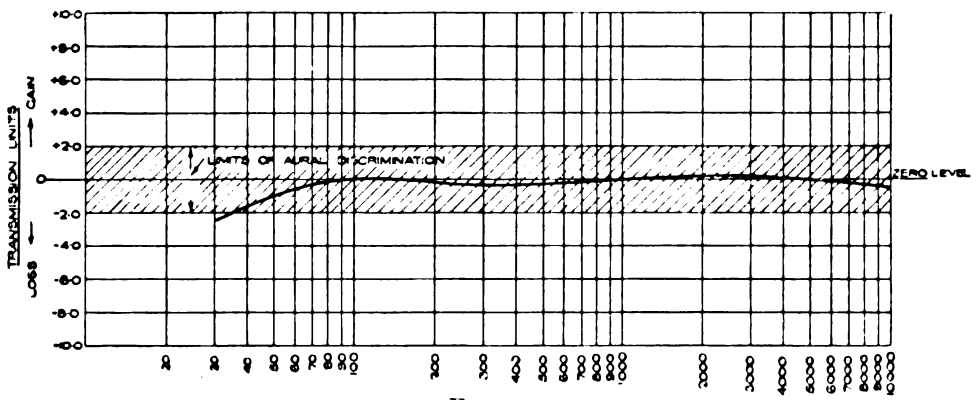

FIG. 2.

Power for the station will be obtained from the local three phase mains. For feeding the intermediate and power amplifiers this will be transformed to 8,500 volts D.C. by three single phase transformers connected in double Y formation together

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with a twin rectifying unit consisting of six water cooled valves, Type CAR.2, the filaments of these being heated by suitable step down transformers from the three phase mains. A combination of iron cored chokes and paper dielectric condensers filters out the alternating current ripple, and a condenser of ten microfarads capacity terminates the smoothing circuit providing a low impedance bye-pass to the lower audio frequencies. The supply for the preliminary stages comes from a three thousand volt D.C. motor dynamo, or more accurately from two separate fifteen hundred volt dynamos connected in series. This supply also has a condenser of ten microfarads across it for the same reasons as mentioned previously. As previously explained the drive has its own battery supply for reasons of frequency stability.

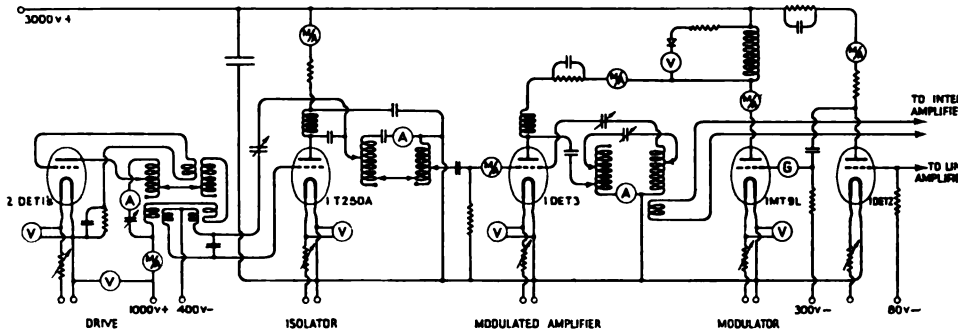

FIG. 3.

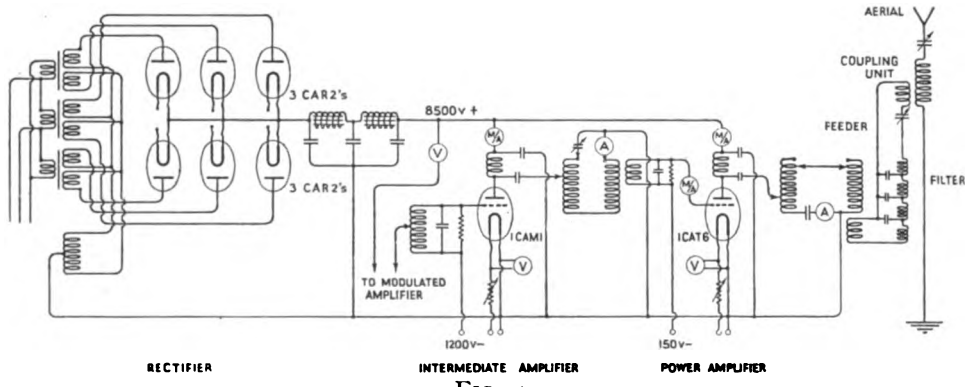

FIG. 4.

The various starter switches, field rheostats, etc., are grouped on a control panel, in order that the set may be operated conveniently from a fixed point. Control of the voltage of the main high tension supply is carried out by adjusting the filament temperature of the rectifiers, permitting adjustment from full voltage to about one quarter the normal. With water cooled rectifying valves this forms a convenient and economical method of adjustment.

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The audio control and monitoring equipment comprises resistance-capacity coupled amplifiers with arrangements for maintaining the input to the transmitter at any desired level. A high quality check receiver and Marconi moving coil speaker, with connections for throwing either direct to the incoming line or to radio enables the quality of the transmission to be observed. The power relations between the various stages are approximately as follows, taking the anode inputs in each case in the carrier condition.

Drive	100 watts
Isolator	150 ,,
Modulated Amplifier	125 ,,
Modulator	360 ,,
Intermediate Amplifier	4 kw.
Power Amplifier	36 kw.

An overall frequency characteristic of the transmitter is shown in Fig. 1, from which it will be observed that the modulation is well maintained at both ends of the audio scale.

A theoretical diagram of connections is given in Figs. 3 and 4, although to avoid undue complications the power supply circuits are not included.

These two diagrams are to be read in conjunction with one another and represent together the complete diagram of connections of the transmitter.

W. T. DITCHAM.

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A DISCUSSION ON SHORT WAVE FADING—II

It has been already suggested, in the preceding section of this paper, that S.W. fading should be considered under two heads—

(1) *The Short Fading of a minute to fractions of a second.*

(2) *The Long Fading of, perhaps, days at a time.*

A brief theory has been formulated as to the causes of these two types of fading, from which it seems that the short fades are occasioned by reflection, etc., from the Heaviside layer, and that the long fades are attributable to magnetic storms.

Curves have been taken of the variation of intensity of signals with time, and an attempt has been made to calculate the variability of such a curve in the case of two rays statistically independent, and in the case of n rays.

By comparing these values of variability with observed values some information has been gained as to the type of rays whose interference produces fading of the first class.

Fading of the second class may possibly be eliminated by the use of varying wavelengths to suit conditions.

Spaced Aerials.

VARIOUS devices for the elimination of fading have been considered, in particular the combination of the rectified signals from two fairly widely separated aerials.

It is an undoubted fact that the fading curves of two widely spaced aerials are entirely different, and if the signals from these two are added without regard to phase, a very considerable improvement might accrue.

There has been very considerable divergence of opinion as to the distance of separation necessary to produce results.

The Dutch experimenters have considered that a distance of 30 feet was sufficient to give marked differences in the fading curves, while those who have experimented on the subject in this Company are convinced that many wavelengths separation is necessary before any appreciable results can be obtained.

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If the results are due to interference, the minimum distance apart of a maximum and minimum can only be $\frac{1}{4}\lambda$ in the very unlikely case where the two interfering rays are travelling in opposite directions. Again, if the two receivers are placed in a line at right angles to the ray, then the variation per wavelength along this line cannot be a large percentage of the mean value if the ray maintains its coherence.

For did such a large variation exist, it would imply a magnetic force in the direction of the ray, which, combined with the vertical electric force, would produce an energy flow at right angles to the ray and disperse it. Since all observations with a direction finder indicate a well-defined ray, such a state of affairs is not possible, and we may conclude that along the wave front the intensity must be constant over many wavelengths.

The conclusion may be drawn that many wavelengths' separation is required, and that it is best to place the receivers along the direction of the ray, rather than along the wave front. It is, however, possible to have different fading curves on two aerials at the same place if the aerials are different. For example, if one is vertical and the other horizontal and at right angles to the ray.

The behaviour of the signals on an ordinary frame aerial immediately show this possibility. For the existence of a wandering minimum, which occurs under certain circumstances, shows that the ratio of the horizontally polarised to the vertically polarised electric force is varying from time to time, and that therefore the fading curve for a horizontal and vertical aerial, or for two mutually perpendicular frames (one in the plane and one perpendicular to the plane of the rays) must be different.

Unfortunately this type of reception is more common for relatively short distance transmission (and is most prevalent just outside the skip distance) and is relatively rare at long distances (where the fading eliminator is mostly required) where the horizontal electric force is generally so small as to be insufficient for combining purposes. Nevertheless, it may be a method worth trying.

Theoretical Gain with Spaced Aerials.

It is possible to calculate the expectation of gain on using two spaced aerials on the assumption that these are so far apart that the resultant E.M.F. at the one aerial can be considered to be statistically independent of the resultant at the other aerial, or, to go further, we can include any degree of correlation between the two. To take the simpler case first: let r be the resultant at one aerial, and r^1 be the resultant at the other, then if r and r^1 are independent, the probability that r lies between r and $r + dr$ and that r^1 lies between r^1 and $r^1 + dr^1$ is .

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$$\frac{1}{\pi^2} \cdot \frac{dr}{\sqrt{1-\frac{r^2}{4}}} \cdot \frac{dr^1}{\sqrt{1-\frac{(r^1)^2}{4}}}$$

in the case of two rays interfering, or $\frac{4}{n^2} e^{-r^2 n} \cdot r dr e^{-(r^1)^2 n} r^1 dr^1$ in the case of n rays.

The mean square values of (r, r^1) are in the two cases :—

$$\frac{1}{\pi^2} \int_0^2 \frac{dr}{\sqrt{1-r^2}} \cdot \int_0^2 \frac{dr^1}{\sqrt{1-(r^1)^2}} \cdot (r-r^1)^2$$

and $$\frac{4}{n^2} \int_0^\infty e^{-r^2 n} \cdot r dr \cdot \int_0^\infty e^{-(r^1)^2 n} \cdot r^1 dr^1 (r+r^1)^2$$

which can be shown to be respectively $4\left(1+\frac{2}{\pi^2}\right)$ and $n\left(2+\frac{\pi}{2}\right)$.

If r and r^1 had not been added independent of phase, the resultants would have been 4 and 2n respectively, so that, in general, adding the two, independent of phase (phase splitting), results in an increased mean square intensity in the ratio $\left(1+\frac{2}{\pi^2}\right)$ and $\left(1+\frac{\pi}{4}\right)$ respectively in the two cases. That such an increase should occur is obvious, for adding independent of phase avoids those occasions when the two sets might interfere by phase opposition. We can now calculate the mean square variation thus in the two cases ;

it is $$\frac{1}{\pi^2} \int_0^2 \frac{dr}{\sqrt{1-\frac{r^2}{4}}} \int_0^2 \frac{dr^1}{\sqrt{1-\frac{(r^1)^2}{4}}} \cdot (r+r^1-2\sqrt{k_1})^2 = x_1, \text{ say,}$$

or $$\frac{4}{n^2} \int_0^\infty r dr e^{-r^2 n} \int^\infty r^1 dr^1 e^{-(r^1)^2 n} (r+r^1-\sqrt{k_2}\, n)^2 = x_2, \text{ say,}$$

where $$k_1 = \left(1+\frac{2}{\pi^2}\right) \text{ and } k_2 = \left(2+\frac{\pi}{2}\right).$$

We find as a result

$$x_1 = 4k_1\left(2-\frac{4}{\sqrt{k_1 \pi}}\right)$$

$$x_2 = 2k_2 n\left(1-\sqrt{\frac{\pi}{k_2}}\right)$$

and dividing by the mean square value in each case to get the percentage variability.

These are : $2\left(1-\frac{8}{\sqrt{k_1 \pi}}\right) = 0{\cdot}105$

and $2\left(1-\sqrt{\frac{\pi}{k_2}}\right) = 0{\cdot}125$

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The percentage variability is reduced in the two cases as was to be expected ; the reduction of variability in the first case is from 0·200 to 0·105, and in the second case from 0·228 to 0·125. The gain in both cases is to reduce the variability to nearly half.

But perhaps it is not quite fair to take the reduction in variability as the only gain. Where the process of limiting can be resorted to, it is only the occasions when the strength is reduced below a certain limiting value which are likely to be troublesome, so we should compare the probabilities that the strength is less than a definite fraction of the whole in the two cases. Thus the probability that the resultant is less than x is

$$\frac{1}{\pi}\int_0^x \frac{dr}{\sqrt{1-\frac{r^2}{4}}} = \frac{1}{\pi}\sin^{-1}\frac{x}{2} \qquad \text{(in the two-ray case)}$$

in the second case, where the two results are added independent of phase, it is:

$$\frac{1}{\pi^2}\int_0^x \frac{dr}{\sqrt{1-\frac{r^2}{4}}}\int_0^{x-r} \frac{dr^1}{\sqrt{1-\frac{(r^1)^2}{4}}}$$

$$= \frac{1}{\pi}\int_0^x \frac{dr}{\sqrt{1-\frac{r^2}{4}}}\cdot \sin^{-1}\frac{x-r}{2} \quad \frac{x}{2\pi^2}\cdot \sin^{-1}\frac{x}{2} - \frac{2}{\pi^2}\left(\frac{\sqrt{1-x^2}}{4} - 1\right)$$

which, when x is small, is nearly $\frac{x}{2\pi^2}\left(\sin\frac{x}{2} - \frac{x}{2}\right)$ and is a very small quantity compared with $\frac{1}{\pi}\sin^{-1}x$

The gain here is very large, and increases in proportion as the limiting signal x (compared with the main signal) is reduced.

Noise level.

In this no account is taken of noise level which fixes the limiting value of x ; on adding the signals from the two aerials the noise level is increased probably about two-fold, so that possibly the limiting value in the second case ought to be 2x, and the corresponding probability

$$\frac{x}{\pi^2}(\sin^{-1}x - x)$$

It is impossible, without a knowledge of the limiting value x, to estimate what the gain will be ; taking $\frac{x}{2}$ equal to $\frac{1}{10}$, then the reduction in probability will be 1·15 to 1,000. That is, if there were 1,000 interruptions in a programme in the first case due to the signal fading below noise level, there should only be one in the latter case. This seems too good to be true, and the excellence of the result may

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only be due to the approximate nature of the formula, but in any case it is certain that the improvement must be greater than 30 to 1.

In the second case, where there are a large number of vectors, the probability that the resultant on one aerial shall be less than x say, is

$$\frac{2}{n}\int_0^x e^{-r^2/n}\cdot r dr = \left(1 - e^{-x^2/n}\right)$$

the probability that the resultant from the two aerials shall be less than x is:

$$\frac{4}{n^2}\int_0^x e^{-r^2/n}\cdot r dr \int_0^{x-r} e^{-(r^1)^2/n}\cdot r^1 dr^1$$

This cannot be evaluated in finite terms, but when $\frac{x^2}{n}$ is small, as it always is, this may be expressed in the form

$$1 - e^{-x^2/n}\left(1 + \frac{x^2}{n} - \frac{x^4}{4n^2} + \frac{x^6}{15n^3} \cdots\cdots\right)$$

in the case where $\frac{x^2}{n} = \frac{1}{10}$, *i.e.*, where the amplitude fades down to $\frac{1}{3.16}$ of its RMS value.

The probability of a fade less than this value is reduced from 0·095166 to 0·00555, or practically 17 fold. For smaller values of x the gain is proportionally greater.

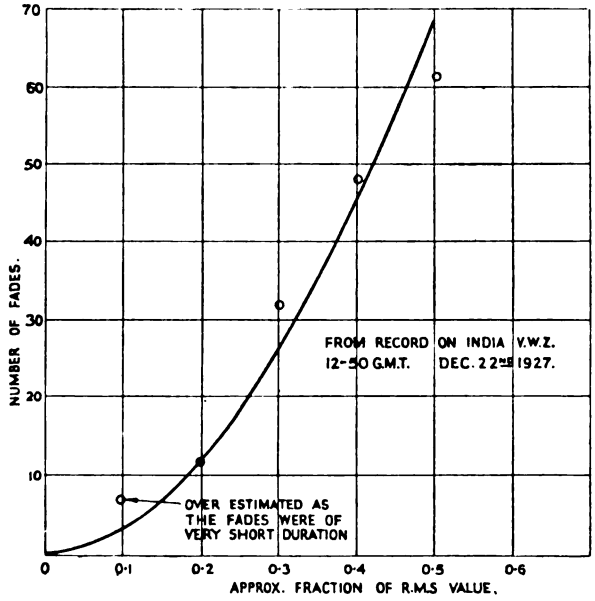

FIG. 3.

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According to the probability theory, the number of fades below a given value x should be nearly proportional to x^2 when x is small.

The curve, shown in Fig. 3, taken from an observed record, illustrates this. It will be seen that this law is a fair approximation to the results.

When this is the case, the theory given for the gain of two aerials over one is very fairly correct. This can be extended to three or more aerials, and it is found that the gain in using three aerials over using two is at least as great as the gain of two over one.

There should, therefore, be a very considerable gain by using as many aerials as possible, so long as these are far enough apart that the received signals in each are statistically independent.

There is no doubt that the object to achieve is to get as great a ratio of signal to noise level as possible in each aerial, and then combine, if the E.M.F.'s at the two aerials are statistically independent.

T. L. ECKERSLEY.

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MARCONI LONG WAVE SHIELDED VALVE RECEIVERS

TYPES R.g.18 and 19

The technical requirements demanded of a modern naval receiver are of a very high order, and it was with a view to supplying this demand that the Marconi Company devoted unusual attention to the design of the R.g.18 and R.g.19 receivers for naval, military and general purposes.

Particular points to which attention has been devoted is their efficient operation over a wide range of wavelengths and control by a minimum number of tuning handles.

An unusual degree of selectivity and amplification has been obtained by the use of screened grid Marconi valves to give two stages of high frequency magnification.

The complete R.g.19 receiver weighs approximately 160 lbs. (75 kilos.), and has overall dimensions of 35 by 20 by 11 ins. (90 by 51 by 28 cms.), and the R.g.18 receiver weighs 70 lbs. (32 kilos.), and measures 34 by 12 by 11 ins. (87 by 29 by 28 cms.).

AS the R.g.18 and R.g.19 receivers differ from each other only slightly in design, it will be sufficient to describe in detail the R.g.19 receiver, and to indicate in what respects the R.g.18 receiver differs from it.

Both of these receivers were designed for use on warships, where space is, of course, a major consideration. It will be appreciated, therefore, that some deviation from ideal construction was necessary in order to limit the space occupied by the receiver.

The R.g.19 receiver is made in three editions at present, each comprising two essential components—the tuner and the amplifier. These two are enclosed in separate brass boxes, very efficiently screened and supported by rubber shock absorbing devices. The three editions cover the following waveranges :—

R.g.19	600—24,000 metres.
R.g.19a	300—10,000 metres.
R.g.19c	500—22,000 metres.

It will be seen from the above that the waverange of the sets is very large indeed, four separate ranges being provided on each receiver to cover this waverange.

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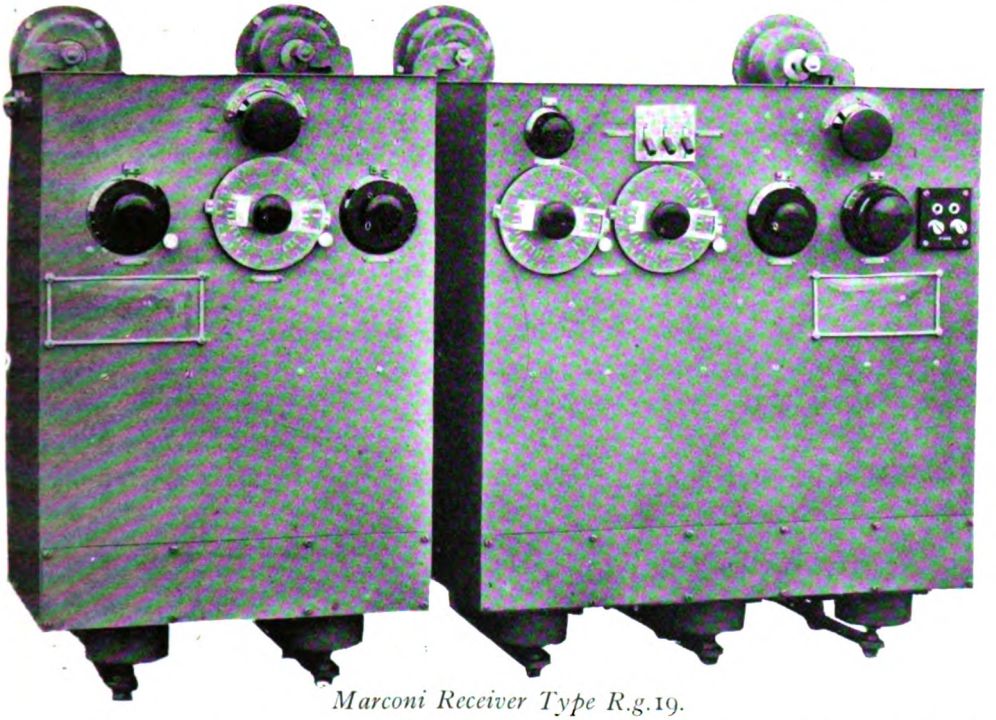

Marconi Receiver Type R.g.19.

The four ranges are obtained by the use of ganged barrel switches, operated from the front of the receiver, which connect the various coils required. All the tuning condensers are provided with four scales, one for each range, as indicated by coloured pointers which correspond to the colours of the barrel switches.

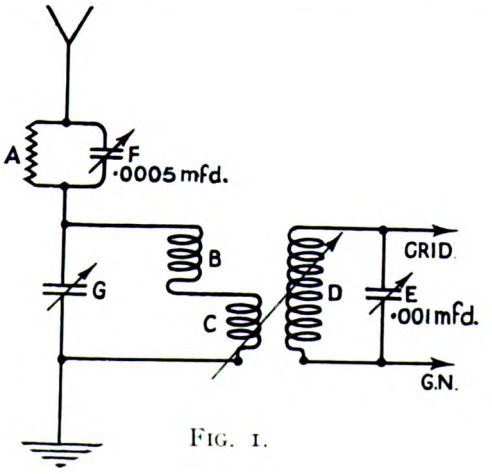

FIG. 1.

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A simplified diagram of the tuner is given (Fig. 1). The two condensers, F and G, have their moving vanes actuated by the same spindle but isolated from each other. G tunes the aerial inductance consisting of coils B and C, and F is simply the coupling condenser from the aerial. It is made variable with G to ensure correct coupling at all wavelengths. A static leak A is provided across F to prevent any charge building up across the condenser. The first closed circuit consists of the inductance D and the condenser E, from which the input is taken to the first high frequency valve.

The amplifier is contained in a separate box, as stated above. It consists of two screened grid high frequency valves, an anode bend detector, a fourth valve which can be used as a note filter or an ordinary transformer coupled stage of audio-frequency magnification or cut out altogether by means of switching, and a fifth valve which can be used as a local oscillator for continuous wave reception.

A simplified diagram of connections of the complete amplifier is given below (Fig. 2).

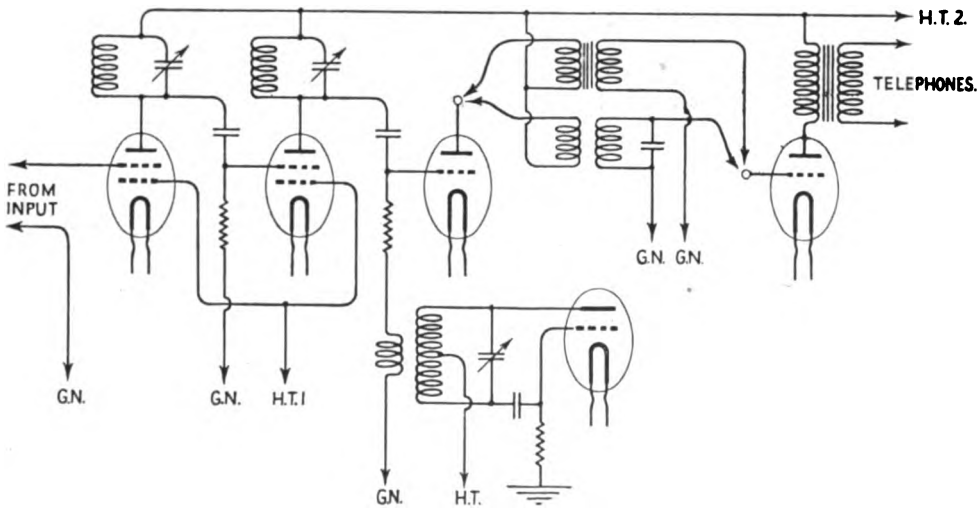

FIG. 2.

It will be seen from the above that the two stages of high frequency magnification are tuned-anode coupled, the two inductances for the tuned anodes being changed by means of the range switches. They are tuned by means of two .001 mfd. variable condensers which are provided (as are also the aerial condensers) with a quick search device to enable a band of about 10 per cent. either side of a spot wave to be searched quickly. This feature makes reception of a station remarkably easy as there are only two controls necessary to be handled.

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It will be hardly necessary here to explain the action of the screened grid valves in full detail, although a short explanation may prove beneficial.

The disadvantage of the ordinary triode for high frequency work is the reaction which may occur through the capacity existing between the grid and anode of the valve. This capacity is too small to be of any importance in low frequency amplification, but it produces unwanted reaction effects and oscillations in high frequency circuits. Many schemes have been put forward to balance out this capacity effect, such as neutrodyning, etc., which were more or less successful. In the Marconi screened grid valve this unwanted capacity is eliminated by an extra grid which is placed between the control grid and the anode and is earthed as far as high frequency is concerned. It cannot be earthed directly as it would prevent any electrons reaching the plate, therefore a positive potential is applied to this extra grid to draw electrons through to the plate.

The characteristic curve of such a valve would be as indicated below (Fig. 3).

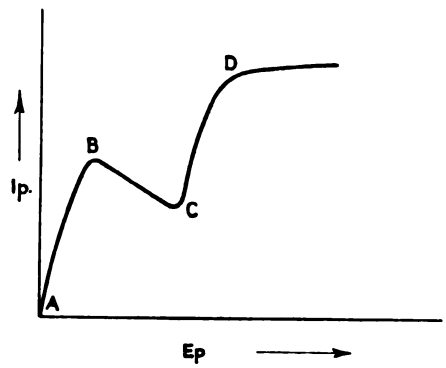

FIG. 3.

From A to B the curve represents a rapid increase of plate current with plate potential, from B to C the current decreases as the voltage rises, due to the fact that new electrons are produced at the plate by electronic bombardment and are pulled back to the outer grid. From C to D this current becomes positive again since now the plate potential is high enough to prevent electrons being dragged back to the outer grid, and from D onwards, no matter how we increase E_p, only a very small increase of I_p will be produced since the saturation current of the valve has been reached.

A study of the characteristics of such a valve will show that we have a valve capable of very high magnification as well as possessing no appreciable grid-anode capacity. With an anode voltage of 120 v. and an outer grid voltage of 80 v. a valve magnification factor of approximately 110 is obtained.

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It is essential in any shielded grid valve set that the screening of the coils, etc., should be very efficient if high magnification is to be obtained, and this fact is paid strict attention to in the design of the R.g.18 and 19 receivers.

The screened grid valve then gives considerably more magnification per stage than it is possible to obtain with the triode, and also is exceedingly stable in its action. It is possible, by using suitable circuits in cascade, to effect a tremendous amplification of high frequency signals by the use of these valves, whilst still keeping the whole amplifier well away from oscillation.

The tuned anode method of amplification is by far the most suitable method of high frequency amplification to use in such a receiver as the R.g.19 on account of the fact that to alter the range, only one coil needs to be changed in each stage, although the overall magnification per stage is slightly less than would be obtained from a stage of transformer coupled magnification.

The amplified high frequency signal is then rectified by an anode bend rectifier, which is chosen because it is less liable to grid blocking through very strong signals or static. In series with the grid circuit of this rectifier, and tightly coupled to the inductance of the local oscillator, is the coupling coil to this oscillator.

For C.W. reception a separate oscillator is used, consisting of a coil with grid and plate tappings tuned by a .001 variable condenser. The former for this coil, which also supports the coupling coil to the detector, is changed for the various ranges by means of the range switch, and a calibration chart is supplied with the receiver for the condenser settings for each range. This condenser is provided with a vernier movement to enable extreme accuracy of adjustment to be made.

The next valve, as has been stated above, can be used either as a note filter or a stage of transformer coupled amplification. The note filter is arranged on the tuned grid principle and the circuit is as below (Fig. 4).

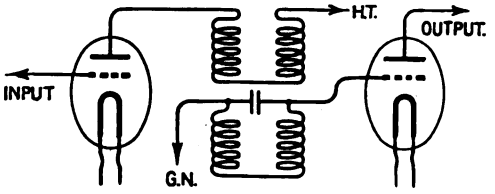

FIG. 4.

Both the grid coil and the anode coil are divided in half and connected astatically. The grid and anode coils are then coupled in such a manner as to make the sense of each set the same. The anode coils are closely coupled to the grid coils and the whole circuit is tuned accurately to 1,200 ∿ by means of a fixed condenser of .01 mfds. capacity. The resonance curve of the filter is very sharp, and the receiver

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relies upon this filter for its selectivity on C.W. to a large extent. More will be said on this point later, however.

When the valve is used as an audio-transformer coupled stage, an ordinary iron core transformer with a ratio of approximately 4 : 1 is used, and no special description of its action need be given here.

The set is designed for use with low resistance telephones, and the output from the last valve is taken to a telephone transformer.

In the case of the R.g.19 series the short wave coils are wound with stranded wire and are very low damped. As the wavelength of the coils increase, however, space does not permit such an ideal design of coil, and the damping of the coil increases, resulting in a slightly less efficiency of high frequency magnification. This effect is most marked on the fourth range, where coils of very high inductance have to be confined to very small dimensions. It should be clearly understood, however, that the selectivity, even on the fourth range, is very good.

The note filter helps in obtaining selectivity to a very marked degree. We can take, as an example, the case of a signal arriving on a high frequency amplifier and note filter, where the resonance curves of the high frequency stage and the note filter are as shown below (Fig. 5). Now if we assume that we are receiving a station

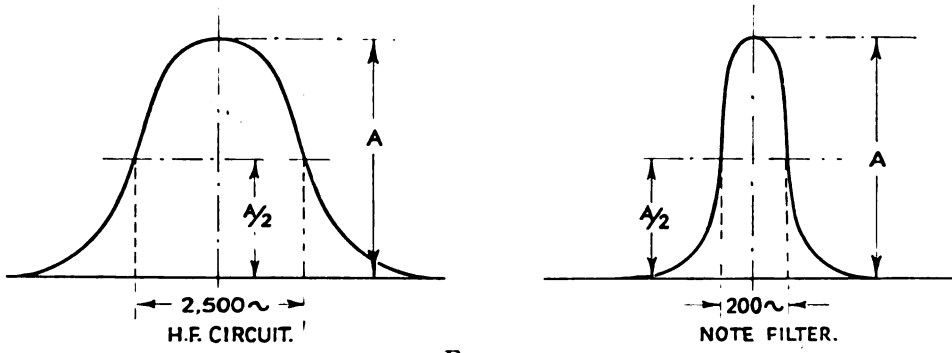

FIG. 5.

on, say, 13,600 λ or 22,000 ∼, and that another station is transmitting on, say, 14,100 λ or 21,200 ∼. Let us call these stations A and B respectively. The difference of frequency between A and B is 800 ∼. Hence, if the maximum ordinate of the resonance curve be made to coincide with the frequency of A, we shall obtain a strength of B approximately 3/4 that of A. Hence, the selectivity of the high frequency stage does not allow these two stations to be separated satisfactorily.

In two stages of H.F. magnification we shall obtain

$$I_A : I_B :: 1 : 9/16$$

where I_A = intensity of Station A

I_B = ,, ,, ,, B

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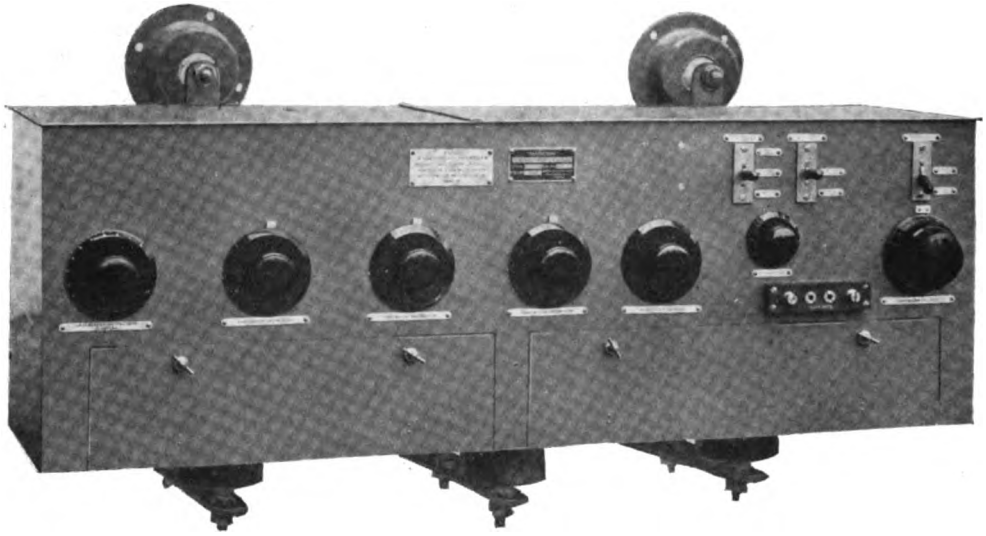
or, in other words, station B will be received at a little over half the strength of station A.

Now let us consider what happens in the note filter. Let us assume that the local oscillator is set to 23,200 ∿ to beat with A at 1,200 ∿. It will beat with B, therefore, at 2,000 ∿. But at 2,000 ∿ the resonance curve of the note filter has dropped to almost zero. Hence the intensity of A is now enormously greater than the intensity of B, and the two stations are adequately separated.



Marconi Receiver Type R.g.18.

In the case of the R.g.18 series, two models are at present made. These are

R.g.18 300—700 λ in one range
R.g.18a 150—800 λ in two ranges.

The tuner and amplifier for these instruments are contained in one box, and consist of the following components :—

Aerial tuning circuits.
2 stages of H.F. magnification.
Anode bend detector.
1 L.F. stage.
Local oscillator.

H.F. amplification is carried out by means of screened-grid valves which are transformer coupled. The transformers have a tuned grid winding and a tightly coupled anode winding. Greater selectivity is obtained in this way, and higher magnification. Such a circuit is practically immune from grid blocking.

As has been mentioned above this means of coupling cannot be resorted to in the case of the R.g.19 on account of switching arrangements,

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MARCONI NEWS AND NOTES

Start Point Beacon Station

Start Point Lighthouse, with Wireless Beacon Station.

THE above illustration is of the Start Point Lighthouse in Devonshire, England, showing the wireless aerials erected by the Marconi Company for use with the Marconi Wireless Beacon Transmitter which has been installed at this station for the Corporation of Trinity House.

The Beacon Station Transmitter, which is installed in the building at the right of the photograph, is a standard pattern Marconi Beacon Station with a power of 500 watts and operated on a wavelength of 1,000 metres, which is the specified wavelength for wireless beacon stations.

Marconi Beacon Stations are entirely automatic in operation. No skilled staff is required, the routine work in connection with the transmitter being easily carried out by the ordinary personnel of the lighthouse.

Each Beacon transmitter has a distinctive identification signal—in the case of Start Point, G.S.M.—which enables it to be identified easily by unskilled listeners. This characteristic signal is normally transmitted twice in each hour, but in foggy weather it is transmitted more frequently for the duration of the fog.

The function of the Beacon Station and its characteristic signal is to enable ships fitted with direction finders to take their bearings from the known point at which the beacon station is situated and thereby to find their true course when approaching the coast.

The Marconi Company has taken a leading part in developing Wireless Beacon

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Stations of the most reliable design. They have already installed stations of this type round the British coasts at

Round Island,
Skerries,
Spurn Lightship,
The Casquets (Channel Islands),
Start Point,
Bar Lightship,
Albatross (Coningbeg, Ireland),

and in the near future further beacon stations of the Marconi type will be installed at

Sule Skerry (Scotland),
Lundy North,
Dungeness,
Kinnaird Head (Scotland),
Cromer,
South Bishop,

and other places, in addition to similar stations for which orders have been received in other parts of the world.

Advantages of Marconi Beacon Stations.

One of the great advantages of the system of position finding in which a Wireless Beacon Station of the Marconi type at a known position is used in conjunction with a Direction Finder on board ship is that the signals are broadcast in all directions and a direct bearing can therefore be taken on the transmitter from any direction at every signal sent out by it. This method is, therefore, particularly suitable for lightship installation, as the swinging of the ship's head does not affect the accuracy of the bearing obtained, and navigators can lay off their wireless bearings on familiar points on the chart. This is an advantage possessed over rotating frame beacons, which are directive, and in consequence require the transmitting station to be fixed in position so that a stationary line of reference for the rotating frame is provided.

One of the many reports showing the reliability of the Marconi Beacon Stations comes from the Humber Conservancy Board. In November, 1927, a Marconi Beacon station was supplied to this authority for use on the Spurn lightship. For a full twelve months this set performed its functions day by day without the slightest fault, and the Chief Engineer to the Board recently wrote to the Marconi Company stating that as the Spurn lightship was coming in from her station for repairs this would be a good opportunity to inspect the Beacon station. This was done and the installation was found to be in excellent order. Considering that it had not even been visited by an expert during the whole time it had been at sea this shows that these stations can be relied upon to carry out their work under the most exacting conditions.

Another instance is that of the Beacon transmitter on the Mersey Bar Lightship at the entrance to one of the world's largest and busiest ports, which the Authorities report to have worked excellently and never to have closed down involuntarily throughout the whole of the twelve months of its operation.

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No. 3

THE MARCONI REVIEW

December, 1928

CONTENTS

THE INTERNATIONAL RADIO TELEGRAPH CONVENTION OF WASHINGTON, 1927 - PAGE 1

THE CHILIAN DESTROYERS "SERRANO" AND "ORELLA" - - - - - - - „ 10

AN EJECTOR UNIT FOR DUPLEX WORKING WITH THE R.G.19. RECEIVER - - „ 11

MARCONI NAVAL TRANSMITTERS - - - „ 15

SHORT DISTANCE COMMUNICATION—II. Development and Performance of the S.A.1. Set - - - - - - - „ 20

MARCONI NEWS AND NOTES - - - „ 26
RE-UNION DINNER
STORM ITEM
MARCONI TELEPHONE INSTALLATIONS

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Marconi House, Strand, London, W.C. 2

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THE MARCONI REVIEW

No. 3. *December, 1928.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

THE INTERNATIONAL RADIOTELEGRAPH CONVENTION OF WASHINGTON, 1927

An Account of the Proceedings at the International Radiotelegraphic Conference, by

COMMANDER J. A. SLEE, C.B.E., R.N. (Retd.)

The Institution of Electrical Engineers has as Chairman of its Wireless Section this year, Commander J. A. Slee, C.B.E., R.N. (Retired), Assistant General Manager of the Marconi International Marine Communication Co., Limited.

Commander Slee's opening address to the Wireless Section delivered on the 7th November last dealt with the proceedings at the International Radiotelegraphic Conference held at Washington in the autumn of last year, at which he was one of the representatives of the Marconi International Marine Communication Co., Limited.

As the result of intensive committee work and the spirit of earnest goodwill which animated all the delegates, international agreement was reached on very many important questions affecting the art of wireless communication, and the decisions arrived at were incorporated in the document now known as the Radiotelegraph Convention of Washington, 1927, the signatures of all the official delegates being appended thereto.

As the Convention comes into effect on the 1st January, 1929, Commander Slee's address, which explains its import, is very opportune, and by the courtesy of the Institution of Electrical Engineers is therefore given in full below.

I FEEL that perhaps it may be of interest to all those concerned with wireless if I say a few words on the recent International Radiotelegraphic Conference of Washington. I should like to divide my remarks into three sections, discussing in turn, what a Radiotelegraphic Conference is, how its work was carried out, and what effect the proposals of the Conference will have when they come into effect as the Radiotelegraph Convention of Washington, 1927.

Conferences prior to 1912.

In the infancy of wireless there were, practically speaking, no national rules, and no international agreements whatever. The Government did not assume control of wireless until 1904. Moreover, in those days, which now seem so dim

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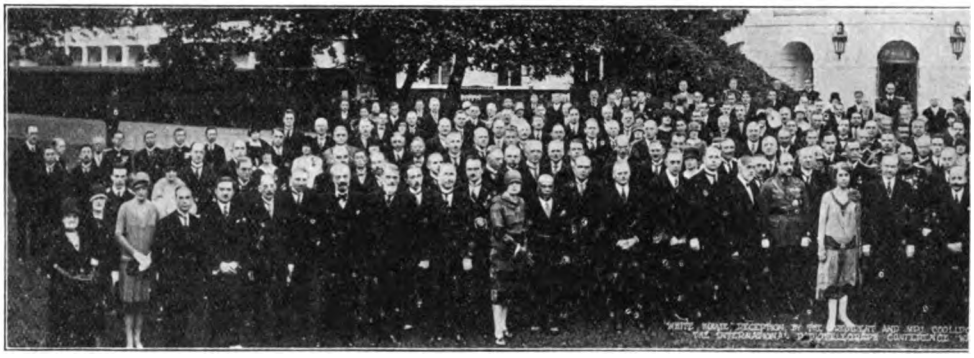

and distant, practically the whole application of wireless consisted of ship to ship and ship to shore communication. Long distance working and working between fixed points were almost unknown. As the communications between ships increased in quantity and importance, and especially as the great value of wireless as an instrument for increasing the safety of life at sea became more fully recognised, the necessity was felt for some international agreement, especially with regard to safety of life at sea questions. As a result of this feeling a meeting was summoned in Berlin in 1903. As some nations were not then in a position to issue regulations, the main work of this meeting was to prepare proposals for a subsequent assembly, which was the International Radiotelegraphic Conference of Berlin, and was held in 1906. There are some gentlemen still intimately connected with wireless who took part in these original discussions.

Perhaps the most striking decision reached at Berlin resulted in the abolition of the " no-intercommunication " principles which had grown up. This was the birth of the principle that wireless is a universal, as opposed to a private, means of communication between the inhabitants of the world.

London Conference, 1912.

The Convention of 1906 was followed by the Conference of 1912 in London, at which was produced the document known as the Radiotelegraphic Convention of London, 1912. This carried on the work of the 1906 Convention, keeping to much the same general ideas, for with the exception of Clifton and Glace Bay Trans-Atlantic Service very little progress had actually been made in long distance communication and in point to point working.

This Convention was almost exclusively concerned with ship work, and with " spark " as a means of signalling. The Poulsen Arc had appeared and was in very limited use, and experiments had been carried out with wireless telephony. The standard detector was a crystal—carborundum was only just coming into use, and the magnetic detector was in common use in most ships. There were very few valves, no air services, and no broadcasting. The wireless interests were strictly professional ; amateur experimenters were very few, and the general public took only the faintest interest in the matter.

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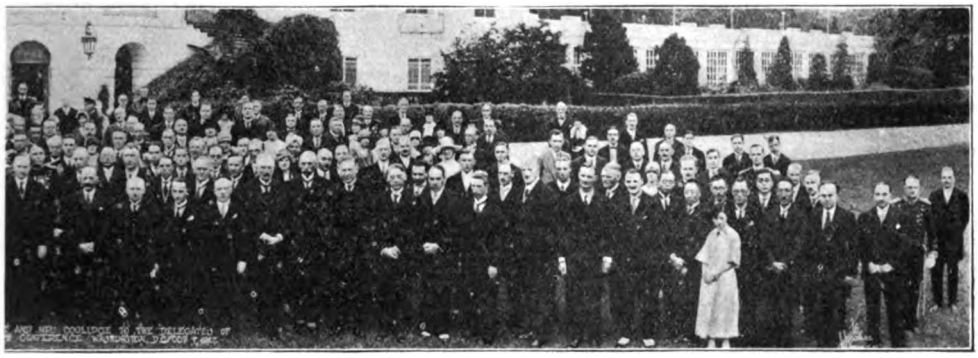

In such conditions the Convention of 1912 was worked out, and the arrangements then made have formed the basis on which all ship work is still carried out. Accustomed as we are to think of the technical side of the subject, we must not forget that the original object of installing wireless in ships was to earn a revenue, and the methods of conducting the truly international accounts—for ships and coast stations of all nations take part in this service—which were settled in 1912 remain almost without alteration to this day.

In passing, it may be interesting to note that the word " Radiotelegraphy " was adopted for international use at the 1912 meeting.

In 1912 it was decided that Radiotelegraphic Conferences should be held at five-year intervals, and that the next meeting should be at Washington in 1917.

But in 1917 the world was plunged in the war, and wireless arrangements could only exist between allies.

Effect of the War on Wireless Communication.

During the war the advance in the technical side of wireless was remarkable ; the wholesale introduction of the three-electrode valve revolutionising both transmission and reception.

The development of valves, especially for reception, was extraordinarily rapid and the use of amplifiers, then for the first time available, put a fresh complexion on the whole use of wireless from a warlike point of view, for, in addition to the enormous increase in the distance at which signals could be received, the use of amplifiers made direction finding a practicable proposition. The introduction of transmitting valves threw open the door to wireless telephony, first of extended use for aircraft, and now in daily and world-wide employment for broadcasting.

The effect of these enormous strides was felt in the warlike organisation of the time, and elaborate inter-allied agreements were worked out and made use of during the war, but these were in essence the very reverse of " International " in spirit.

After the end of hostilities it was clearly necessary to bring all nations together again to recommence the series of international conferences, but in addition to the difficulties of rearranging the old Convention so as to bring it into line with the

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vast technical improvements made in the interval, there remained the diplomatic problem of getting the nations so recently and so bitterly at war to meet in friendly discussion on so thorny a subject. The technical improvements of the war and the time immediately after it had given stations a world-wide range and world-wide powers of interference, so that there was every prospect of acute differences arising between rival claimants for the wavelengths necessary to carry on the wireless communications of the world.

In many countries, certainly in this country, expert committees were kept in almost constant session, trying to solve these most difficult points. Schemes were prepared, which displayed the most remarkable ingenuity, for the division of the globe into sections in which various wavelengths could be used with appropriate powers, the shorter waves, which were to be used by the lower power stations, being repeated at suitable distances.

Washington Conference, 1923.

In 1923 an inter-allied committee was got together in Washington for the purpose of working out some document which could be circulated to the world as a basis of truly international discussion. This meeting used the old war-time inter-allied arrangement as a foundation from which to start, and in due course the result of their labours was circulated, and with it an invitation to all nations to attend at an International Radiotelegraphic Conference as soon as it could be arranged. Again every nation set up committees to consider this draft, which was generally called the "green book," and finally government rejoinders were forwarded to Washington, where the original "green book" with all the remarks and counter proposals, and explanations of all the 74 states likely to be represented, were printed together and circulated for further discussion under the name of the "brown book."

Thus, some kind of agreement was worked out, so to speak, by correspondence, but during the whole period the difficulty and complexity of the subject was added to by the rapid growth of the Broadcasting Service, and the enormous weight of public opinion which it carried, especially in the United States, and to a slightly less extent in this country. In a word, the old professional wireless services—Naval, Military, Air Force, Post Office and Commercial—found themselves being elbowed out of the ether by the demands of this vigorous new claimant for a share in the available wavelengths.

Then, as a final complication, just as the ponderous documents which I have sketched out were beginning to produce some kind of probable concord, came the reintroduction of short waves, topped up by the appearance of the beam system which only proved itself to be a truly practical proposition a few months before the Conference assembled.

Washington Conference, 1927.

We now can appreciate the conditions under which the Conference of 1927 assembled at Washington. There were delegates from 74 governments, speaking 52 languages. The subject to be discussed had changed out of all recognition since the last fully international meeting, and the elaborate and laborious preparations had undergone a great change in perspective—due to the recent triumph in short wave work. On top of this lay the fact that the administrative side of the proposals opened up a wide cleavage of view, due to the fundamental differences between the

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constitutional powers of the U.S. Government with regard to the regulations which it could enforce on its subjects, and the powers of most of the European States. The Government of Canada is in nearly the same position in this respect as that of the United States. To these must be added the claims and desires of commercial companies and the Broadcasting Union, and a certain soreness between some of the nations—not necessarily on subjects connected with wireless. There is no wonder then that some at least of the 400 delegates and representatives thought that yet another postponement was more probable than an agreement.

Sub-Committees of the Conference.

The Conference, consisting only of official delegates from the various countries, met and drew up rules of working, dividing the work into sections under eleven committees. It was also decided that the representatives of the Wireless Companies and other wireless interests, who had been invited to be present, might attend the main and committee meetings, and address the meetings by permission of the Chairman, but that they had no voting powers.

The great changes which had taken place in the subject made the distribution of work among the committees difficult, but by goodwill and give and take the matter was straightened out, either by handing over parts of the work from one committee to another, or by joint meetings of two or more committees.

These formal committees split up into somewhat less formal sub-committees and in many cases these were further divided, there being no other hope of carrying the work through in any reasonable time.

This fine distribution of work made it necessary for each of the maritime countries to be represented simultaneously in several rooms, and the daily working hours of all members of the delegations became very long.

Even this sub-division was not adequate to the task of finding a path through the intricacies of proposal and counter proposal, especially those concerning the allocation of waves to the various services, and the regulations for the conduct of ship communications. It is worth while recalling the fact that the first of these had always presented the most grave difficulties, which had just been redoubled by the sudden appearance of short waves, and that the latter had formed the bulk of all previous Conventions.

Language difficulty.

In order to get on, the sub-committees were still further split up, small coteries meeting after dinner, as there was no other time available to discuss detail and prepare papers which the more formal bodies higher up in the scale might study and discuss. These small meetings ranged from about ten members down to two, and in many cases the language difficulty was solved by producing papers in parallel columns in French and English. There was one small detail which caused a lot of bother for the first week or so—the difficulty of drawing a clear distinction between the advisory and mandatory sense when using the French conditional sense. The most intricate of the subjects dealt with, that of the distribution of wavelengths below 100 metres, was worked out by a small party which remained in being for some weeks and finally became known as the " Kilocycle Club."

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The language question was settled as follows. Volunteers from among the delegates, and the representatives of private companies, were appointed as "Rapporteurs" to the various committees and sub-committees which had any formal existence. It was the duty of these gentlemen to act as secretary and as interpreter. The official language was French, as is usual at these meetings, and any delegate who so wished might ask for a translation into English, and any speech made in English was translated into French as a matter of routine. The drafts of all minutes embodying the proposals of the various gatherings were agreed at the next meeting and handed by the "Rapporteur" to the Drafting Committee, which was responsible for cleaning them up into correct French and into the literary style of the rest of the work.

The way in which these gentlemen performed their work was truly admirable. Technical discussions, involving long and complicated arguments, entirely impromptu, were translated instantly and tersely from one language to the other, and I do not think that any speaker ever had cause to complain of inaccuracy, or lack of appreciation, of the points of his arguments.

In the smaller and less formal meetings the Chairman himself usually did any necessary interpreting, and we were indeed fortunate in finding enough gentlemen with an expert knowledge of the appropriate branch of the subject, and sometimes as many as three European languages, to conduct these intimate and vital discussions.

Final draft of Regulations.

Work was carried out in this way for about six weeks, a steady progress being maintained in sub-committee with but little to show for it on the surface, and then began the period of sub-committees reporting to committees and committees reporting to plenary sessions. The apparent progress during this period was very rapid, and a stranger attending one of the later plenary sessions might have thought that important regulations were being rushed through with indecent haste, but the discussions had all taken place outside, and a real agreement had been reached. The only detail requiring careful scrutiny at this stage was the exact drafting of those paragraphs which embodied the work of two or more committees.

Particular care was necessary in the exact wording of the administrative regulations, in order that the largest possible number should be acceptable as they stood to the United States and other countries whose constitutional position differed materially from that of the bulk of the European States. This object was achieved in a most satisfactory manner, none of the Convention proper, and only a very small proportion of the regulations being left in an appendix which only a small number of governments were unable to sign. It should not be thought that those countries which found themselves compelled to abstain from signing the whole document did so on account of any disagreement with the letter or spirit of the article in question. Abstention was only due to the legal inability of these states to undertake to enforce regulations which were outside their constitutional powers.

Throughout all the long preliminary discussions, and during the Conference itself, the government officials had at their disposal, and made free use of, the services of the representatives of the Commercial Wireless Companies. The most cordial relationship existed, and the closest co-operation took place. At many of the smaller sub-committees—that is to say, during the most complicated negotiations

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of detail—there were almost as many unofficial members, consisting of representatives of commercial companies, as there were national delegates. Indeed, in some few instances it was difficult to say in which capacity individuals were sitting, as some nations had to delegate temporarily the national voice to the representative of a commercial company, in order that enough people might be available to attend the large number of simultaneous sub-committees.

This, I think, will give an outline of the work which goes to the making of an International Radiotelegraphic Convention, and to the methods by which an International Conference can arrive at an agreement, even on such a complicated subject.

International Convention, 1927.

Turning now to the provisions of the Convention itself, we find that it consists of a short formal Convention, properly so called, consisting of 24 articles, couched in the broadest possible terms, in which the governments concerned bind themselves to work together and to enforce the regulations attached to the Convention, and to repress illicit work. It also sets up the principle of arbitration in case of disagreement, and restates the former principles of priority for distress messages from ships and of general inter-communication between ships.

Then follow the Regulations which are enforced under the Convention—34 in all as now printed. In order that the discussions might be kept to some kind of framework, the numbering of old articles was adhered to, with new articles interposed. As a consequence, the arrangement of articles, and the distribution of the matter which they contain, are perhaps capable of improvement, but all who were present at the discussions know that it would have been quite impracticable to carry the re-arrangement of the articles any further than has now been done.

The technical side of the regulations is based on the idea that, there are certain wireless services carried out by stations distinguished by the corresponding name, and that types of emission shall be classified and their uses controlled according to this classification. The "Wireless Services" are "Fixed," "Mobile," "Broadcasting" and "Special," the names being self-explanatory, except with regard to Special Services, which include Time Signals, Direction Finding, Standardised Waves, etc., and might perhaps have been better called "Miscellaneous Services." A generous allocation of the shorter waves is also made to amateurs for experimental purposes.

Subdivision of Wavelengths.

Waves are divided, in fact, into four clasess, viz., A1, A2, A3 and B, and for all practical purposes these may be interpreted into ordinary colloquial language as Continuous Waves, Interrrupted Continuous Waves, Telephony, and Spark. Technically speaking Article 5 is the core of the matter, as it lays down the wavelengths to be used for the various services, and goes as far as is possible in the direction of discouraging the use of spark. Almost any person could produce a corresponding Article which would please some interest better than Article 5; indeed, I suppose it may be said that every country and interest represented at Washington was prepared with a detailed proposal on this subject, but the point to be remembered is that all of these different interests gladly accepted this article as a workable basis on which the wireless work of the world could be carried out.

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In this, as in several other closely detailed regulations, it was necessary to use wording which would prevent lawless and unneighbourly practices, but which would not close the door to future progress along lines as yet unforeseen, and, where possible, to provide for a certain amount of flexibility so that future contingencies might be met without the necessity for summoning a special Conference to rectify the wording chosen by that held at Washington.

Designation of Wavelengths in terms of Frequency.

The Convention agreed to the introduction of the practice of designating waves by their frequencies, expressed in kilocycles per second, but no very great progress has yet been made in this direction.

Distribution of Wavelengths.

The distribution of waves among the different services is a remarkable piece of work. In a word, every service clamoured for about half the available waves, and so far as short waves were concerned, there was not much firmly established data to go upon. The tact and patience displayed by all concerned is beyond praise, and by the time the proposals reached the Technical Committee there was not a single dissentient voice.

Very nearly the whole of the remainder of the regulations deal with the Mobile Services. The position with regard to the Fixed Services is comparatively simple. The regulations admit, as a general principle, of one wave being allocated to one station. To that wave the station must keep within very narrow limits, and so long as it keeps within those limits there are no restrictions. The Administrations—that is, the Government Departments concerned—are responsible that suitable waves are allotted, and once a station is granted a licence to work on a certain wave the station is left free to make the best use that it can of the privilege.

Ship and Aircraft Stations.

With mobile stations the reverse is the case. There are a huge number of ship stations—about 12,000—all moving about. They must all be able to get into touch with one another or with the land. They represent many nationalities and use as many languages and as many coinages. Although fixed stations have the power to produce world wide interference, unless properly regulated by international agreement, yet the mobile stations must be capable of world wide and truly international inter-communication. Hence the volume of detail regulations.

The men who work the stations must be up to a high standard of competence, otherwise one incompetent man may obstruct the communication of several ships, perhaps for hours. Apparatus must be kept up to a definite state of efficiency. Hours of watch must be arranged. There must be an international code of signalling and of procedure. Accounts which are to be rendered in many languages and using many currencies must be standardised in form.

Above and through all this ride the regulations made in the interests of Safety of Life at Sea, for wireless has proved itself time and again to be a most potent agent in improving the chances after a casualty, as well as in the prevention of casualties. The ship service must thus be regulated so as to provide for the best touch between ship and ship and between ships and the shore, for in this way, both the safety of life at sea and the convenience of the average ship are best served, and, in addition, there is the numerically small but important class of great liners which keep up a

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heavy stream of traffic of the private affairs of their passengers. Other lines of communication have to be opened for the benefit of such craft, and all the regulations governing all these complex matters must be truly international in character, clear, binding, and yet flexible enough to permit of unforeseen contingencies being encountered and satisfactorily dealt with.

Detailed as these regulations are, there are yet finer distinctions required, and these are kept in being by statements as to individual practice now in use, which are published in the International List of Radiotelegraph Stations, commonly called the " Berne List."

The regulations applicable to aircraft are similar in principle to those for the control of ship working. So far, there is no regular exploitation of commercial communications to and from aircraft, but no doubt such a series will come into being when long distance flights become frequent. There is no opportunity for a commercial telegraph service while flights last for only a few hours.

The detail regulations as to the procedure to be followed in the case of ships in distress, and for the handling of other urgent navigational messages, represent the result of the accumulated experience of years.

After the regulations proper appear numerous appendices, which support the regulations in a more detailed fashion. They include a remarkable table of authorised abbreviations which are known all over the seven seas, and are used so much by the senior telegraphists in everyday life that some of them have developed into a kind of slang.

Finally, the book is completed by the additional regulations (7 in number) nearly all dealing with the details of accountancy, which certain states were unable to sign, for the reasons previously mentioned.

Summary.

Taking a broad view of the whole of the Convention and its regulations, and trying to look into the future for a few years, we may say that the Convention will have the effect of regularising existing practices without fixing them so firmly that progress will be impeded. So far as is possible, without inflicting an intolerable hardship on the shipping world, progress will be accelerated in the direction of the reduction of the interference caused to other services by the Mobile Service. There will be a general reduction in interference, brought about by a more scientific use of the means of communication now available, and above all the foundations have now been firmly laid for a series of similar international meetings, at which there will be less to be done at one blow, and fewer conflicting requirements to be satisfied, and from which real improvements in the international wireless arrangements can be looked forward to with confidence.

This, I think will give a fair idea of the Radiotelegraphic Convention of Washington, 1927. As far as is consistent with brevity I have tried to explain its origin, its production and its aims. I feel that it is in every way a remarkable and important document, most of all from the point of view of international peace and goodwill. The evolution of a perfectly agreed document, by no means vague or lacking in detail, from such a mass of proposals and counter proposals, often directly opposed in principle as well as in detail, after so long a period of intensive progress and so soon after active hostilities, seems to me to be a veritable triumph for diplomacy and the happiest augury for future international understanding.

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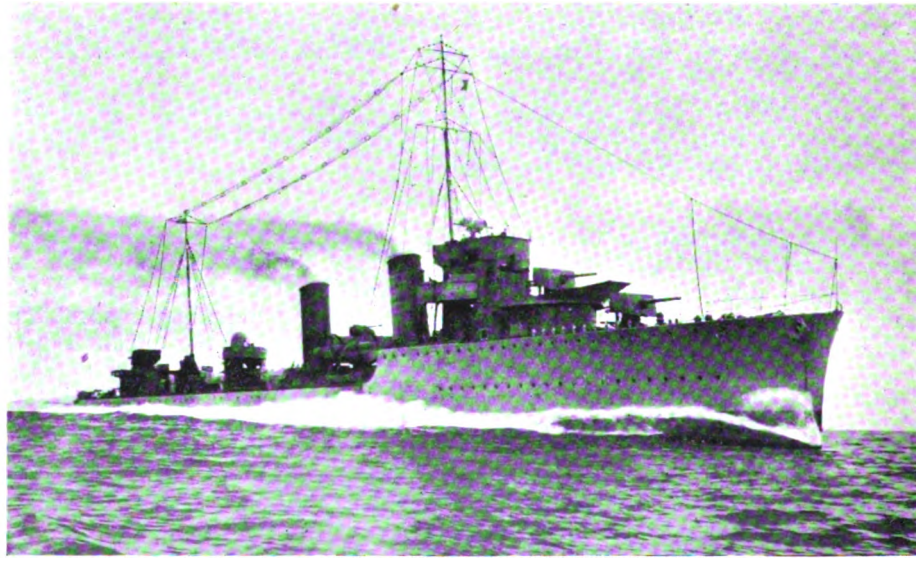
THE CHILIAN DESTROYERS "SERRANO" AND "ORELLA"

The destroyers ordered by the Chilian Government, and now being constructed by Messrs. J. I. Thornycroft & Co., Ltd., at Southampton, are fitted with wireless equipment supplied by the Marconi Company. The apparatus is comprehensive and of the latest design, and the whole installation represents a very efficient and modern equipment.

THE Chilian destroyers "Serrano" and "Orella," which have recently successfully completed their wireless equipment acceptance trials, are fitted with Marconi apparatus of the latest type.



These trials mentioned above were carried out under severe working conditions in harbour and at sea. Good communication was maintained with Lisbon and Chelmsford throughout the tests.

The photograph shows the destroyer "Orella" at sea, her aerial equipment being clearly indicated.

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AN EJECTOR UNIT FOR DUPLEX WORKING WITH THE R.G.18 AND 19 RECEIVERS

When simultaneous reception and transmission have to be practised in the same locality, some form of circuit is necessary for use with the receiver to eliminate the powerful field set up by the neighbouring transmitter.

In the November issue of the "Marconi Review" an account was given of the R.G.18 and 19 receivers, which are coming into general use for Naval Service. The instrument here described is an ejector unit specially designed to be used with these receivers, for use on board ship where receiver and transmitter are in close proximity. The efficiency of the instrument is such that a frequency separation of 20 per cent. is quite sufficient to enable signals to be received while the main transmitter is in use.

THIS ejector unit has been designed to enable duplex working to be carried out with certain types of ship installation, especially where an R.G.19 Receiver is used in conjunction with a type T.N.1 Transmitter.

The apparatus renders possible reception on the receiver when the main transmitter is in use.

Two examples may serve to demonstrate the capabilities of the instrument under severe practical conditions.

With 10 amperes in the transmitting aerial (which was tuned to 300 metres), under which conditions 150 milliamperes were found to be induced in the receiving aerial, 2LO on 361 metres could be received on a loud speaker with no interference from the local transmitter.

Again, with the receiver tuned to 600 metres, and the transmitter being keyed on a wavelength of 700 metres (15 per cent. wavelength separation), with 18 amperes in the transmitting aerial, the coast stations FFB (Boulogne) and OST (Ostend) were always perfectly readable at Chelmsford.

The arrangement of aerials under which this test was carried out is shown in Fig. 1, and it will be appreciated that these conditions represent the most severe that are likely to be met with in practice.

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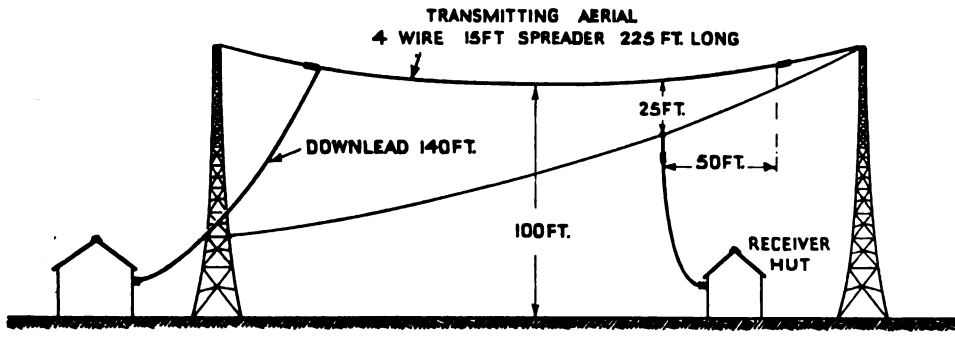

FIG. 1.

A simplified diagram of the connections of the ejector is shown below (Fig. 2), from which it will be seen that the instrument consists of two units inserted between the receiving aerial and the receiver.

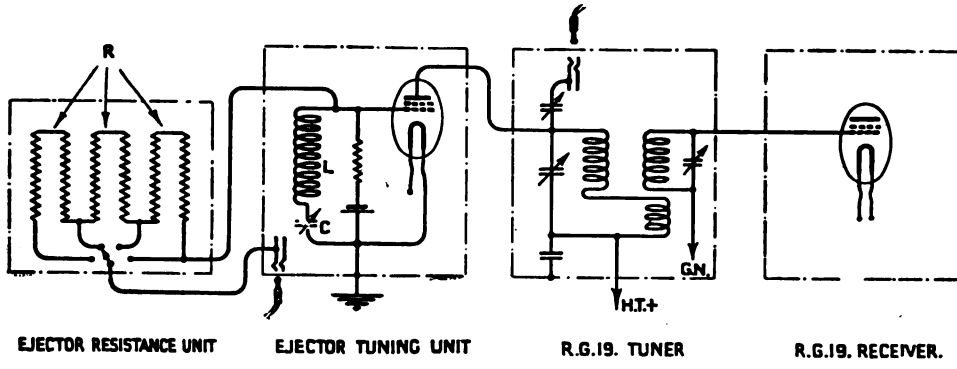

FIG. 2.

The ejector tuning unit will be seen to utilise an S.625 Valve. For duplex working the aerial is connected to the grid circuit (LC) of the tuning unit via the resistance unit R. The tuning range of this grid circuit is 300-4,000 metres, which covers the waveranges of all the types of transmitters with which it is intended for use. The anode circuit of the ejector valve is what corresponds to the aerial circuit of the R.G.19 in simplex working. It is therefore tunable over the receiver waverange.

Now if the circuit LC be tuned to the transmitter wavelength, it will possess a very low impedance to this wavelength. Hence the voltage set up by the transmitter signal will be very small. To all other wavelengths, however, the circuit LC will offer a high impedance, and a high voltage will be impressed on the grid of

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the ejector valve. The receiver, being tuned to the frequency of the desired signal, will amplify these voltages in the normal manner.

The ejector resistance unit is necessary for various reasons, one of which is to limit in certain cases the currents induced by the local transmitter.

The change from simplex to duplex working is effected by the simple process of removing the insulated aerial plug from the receiving tuning unit and inserting it into the ejector tuning unit.

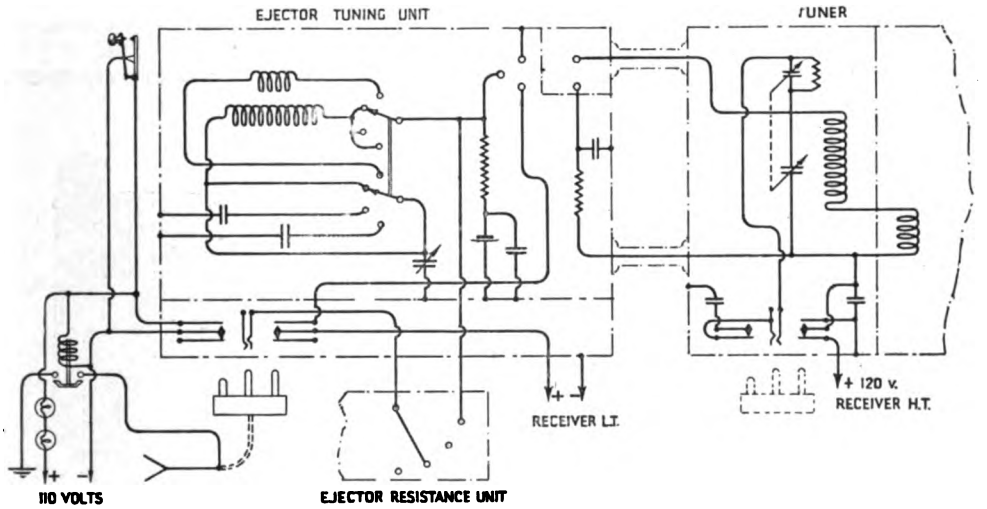

FIG. 3.

In Fig 3 is shown the complete diagram of connections, and it will be seen that the above operation effects the following changes :—

(1) The aerial is disconnected from the first circuit of the R.G.19 tuner, and this circuit is blocked off from earth.

(2) High Tension is switched through to this circuit.

(3) The capacity of the aerial is replaced by a condenser so that the calibration is unaltered.

(4) The ejector valve filament lights.

(5) The aerial is connected to the ejector circuit.

(6) The listening through relay, which earths the aerial when the main transmitter is keyed under simplex, is rendered inoperative.

In considering the effect of the ejector resistance unit, we see that the impedance offered by the circuit LC to the incoming local transmitter signal is r, the ohmic resistance of the coil, for the total impedance.

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$$Z = \sqrt{r^2 + \left(Lw - \frac{1}{Cw}\right)^2}$$

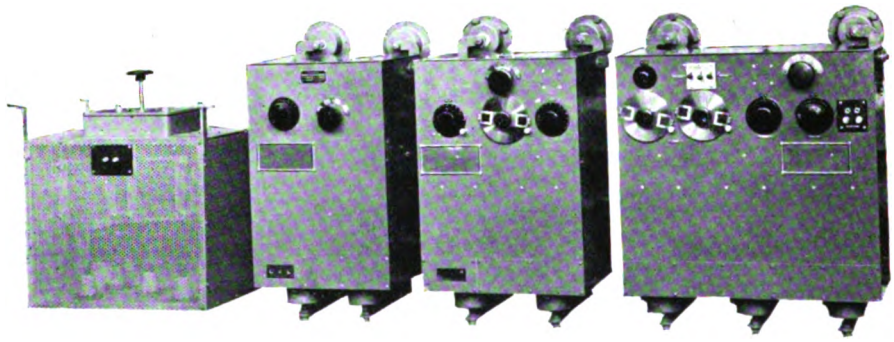
Hence if $w^2 = \frac{1}{LC}$

$$Z = r$$

Now, if the transmitter is inducing a current I into the receiver aerial, the voltage set up across the ejector valve grid will be

$$V = rI$$

There will be a limiting value for this voltage, beyond which the signal cannot be cut out. The value of r is fixed and so it may be necessary to reduce I, which can be done by increasing the value of R in the ejector resistance unit.



It will be found necessary for any given conditions to increase the ejector resistance R with the wavelength of the local transmitter.

In the illustration given above the resistance unit is shown on the left and is made of robust construction owing to the fact that it has to dissipate a large amount of energy picked up by the receiver aerial from the transmitter. The second unit comprises the ejector tuner circuit and the third and fourth units are the tuner and amplifier of the R.G.19.

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MARCONI NAVAL TRANSMITTERS

Type T.N.1.

The exacting requirements demanded from all wireless apparatus on board warships have resulted in the design of a complete series of Naval Transmitters for use on all types of naval vessels.

The power of these sets varies from 50 watts to the aerial to 4 kilowatts, and they are arranged for transmission on either C.W. or I.C.W.

The most important features of the transmitters are—

(1) *Robust construction.*

(2) *Simplicity of operation.*

(3) *Large Wave Range.*

(4) *Flexibility of power.*

(5) *Constancy of wavelength.*

(6) *Safety in operation.*

A detailed account of the T.N.1 transmitter which possesses many points of interest in its design is given below.

THE type T.N.1 Transmitter has been designed as a moderate power compact unit with a particularly easy control, and a considerable waverange transmission can be effected on C.W. or I.C.W. over the whole of the wavelength range of 300 to 3,000 metres with a power of 3 kilowatts to the magnifier anode. The various combinations of condensers and inductances, I.C.W., note control, etc., are operated from the front panel of the transmitter, together with suitable interlocks to prevent accidental damage when under power. Here also are the instruments necessary to read the various filament voltages, feed currents, and high tension voltage. There are two separate A.C. single phase supplies to the set; one for lighting the valve filaments, and the other for power.

Power to the transmitter under keying conditions is very constant, since the absorber method of keying is employed. The grid positive potential for the absorber, and the grid negative bias for the magnifier valve, are obtained from another but smaller machine.

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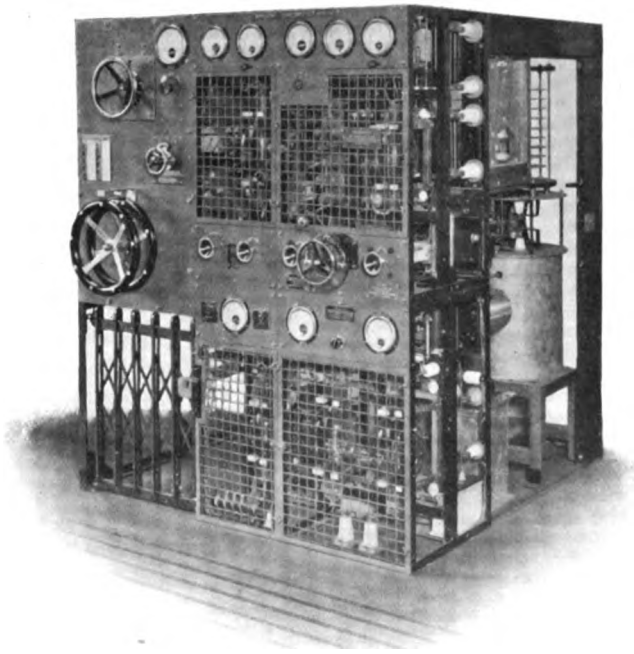
The valves, of which there are five in number, are all visible and replaceable from the front of the panel, being protected by metal screens. The removal of any one of these screens immediately shuts off the power. Sliding gates enable access to be obtained for inspection purposes, the power being similarly removed when the gates are opened.

In order to study the transmitter in detail, its various circuits may be classified under four heads, as follows :—

(1) The rectifying system.
(2) The drive or master oscillator.
(3) The magnifier and aerial high frequency gear.
(4) The absorber.

Taking these in the order mentioned above :—



1.—The Rectifying System.

A single phase 500-cycle 350-volt supply from the main alternator is connected through a power relay to the primary of the power transformer—housed in the transmitter—and is then transformed up to approximately 20 kilowatts. Thus there is a potential difference of 10 kilowatts between the centre point of the

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secondary which is earthed, and the ends of the secondary which are connected respectively to the anodes of the two rectifying valves (M.R.7.A.'s), each of which becomes alternatively conductive for each half cycle. This maintains the smoothing system to which the valve filaments are connected at a potential of 10 kilowatts. The smoothing system consists of an oil-cooled low frequency choke shunted to earth on either side by a large capacity condenser. High tension D.C. is thus available, capable of easily maintaining a normal output of 450 milliamperes. The smoothing condensers are automatically discharged when the power is cut off, through a megohm leak, which serves also as a voltmeter resistance. In addition, a hand-operated shorting device is fitted.

2.—The Drive.

The drive or master oscillator controls the wavelength and energy transferred to the magnifier circuit. It is so designed that a simple four-position switch mounted on the front of the set, makes all the adjustments to the high frequency circuits to cover the whole range from 300 to 3,000 metres the adjustment of the fine graduations of wavelengths being effected by means of a calibrated control, also on the front of the set, which operates a variable condenser. The switch is so connected that a change of position not only adjusts the coil tappings, but enables a variable oil or air condenser to be used alternatively with a long or short wave inductance. It also has a mechanical lock which only allows the circuit to be broken by the switch at a given point where an electrical contact opens the power relay, thus rendering the circuits "dead." All the inductance coils are arranged astatically to prevent extraneous coupling due to stray field. The high tension supply to the drive oscillator valve—an M.T.6—is reduced to a suitable value by a series resistance. This resistance also serves as the absorber resistance in the anode of the absorber valve.

3.—Magnifier Valve and Aerial High Frequency Circuit.

This valve serves to amplify the oscillations set up on its grid by virtue of the drive coupling. Since, however, the anode of this valve is supplied with high tension D.C., it would—but for the neutrodyne condenser—oscillate due to its own self-capacity on some part of the wave-band. The function of this neutrodyne condenser is to set up an equal and opposite balancing voltage—the "bridge" circuit thus formed being shown in the diagram below.

A pure grid swing provided by the drive oscillator is therefore obtained and is then superimposed on a steady applied negative potential. The neutrodyne condenser adjustment, once found, needs no alteration for change in wavelength. The aerial system is a direct load on the magnifier valve, and, as it is tuned to the drive, will oscillate at the same wavelength. This is a great advantage where there are likely to be fluctuations in the aerial constants due to aerial swinging, as no change in the radiated wavelength can take place. The anode feed current of the magnifier

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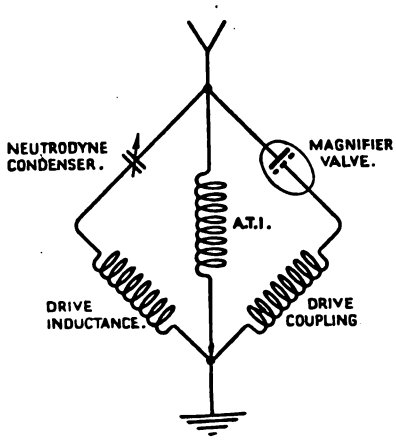

FIG. 1.

valve for normal position of anode tap should be approximately 300 milliamperes at 10,000 volts. At this power the valve anode will be heated to a bright " red," the normal temperature for this type of valve. A three-position selector switch enables any desired adjustment of tap to be obtained. A combination of fine and coarse inductance taps controlled by two rotary switches, which also insert aerial series condensers, with a drum type variometer, makes it possible to tune to any desired wavelength. The rotary switches automatically cut out the unused sections of aerial inductance, preventing undue high frequency losses and voltage strain. An aerial current indicator is situated adjacent to these aerial adjustment controls on the front of the panel. A mechanical device registers the number of variometer turns in use, and special spring-buffers prevent the drum being rotated beyond its limit. To obtain I.C.W. a motor driven interrupter makes and breaks the grid leak and applied negative potential circuit of the magnifier valve at a speed depending upon the note required. The valve ceases to oscillate during the " break " period, but is restored to a normal oscillating condition when the circuit is again completed. A tapped motor field resistance allows variation of motor and interrupter speed. Normally three note frequencies are available—600, 900 and 1,200.

4.—The Absorber.

The absorber valve plays the part of a switch, instantly transferring the load to the absorber system when not required in the high frequency circuits and vice versa. This is accomplished by means of a relay operated by the manipulating key, which reverses the potential on the grid of the valve. Thus, when the key is closed, the grid is made highly negative, the valve becomes non-conductive, and the load passes to the transmitting circuits. When the key is opened the grid becomes positive, the valve highly conductive, and the load is absorbed by the absorber

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resistance, which is adjusted so that the load is approximately equal to the transmitting load. Actually this resistance serves the dual purpose of absorber and drive valve anode resistances, thus ensuring a very clean cut off of aerial energy when the key is opened. The grid potentials required for the absorber and magnifier valves are obtained from a potentiometer having an earthed centre-point, and excited by a small generator. An aerial calibration chart is supplied which gives the actual adjustments for every 100 metres. These adjustments vary with the aerial in use, and the figures are therefore logged when the set is installed. An overload relay is provided, and is adjustable from the front of the set. Filament transformers, with variable resistances for adjusting individual filament voltages, are mounted on the panel. The entire set, with the exception of the machines and switchboard, is 5 ft. wide, 5 ft. deep, and 7 ft. high overall.

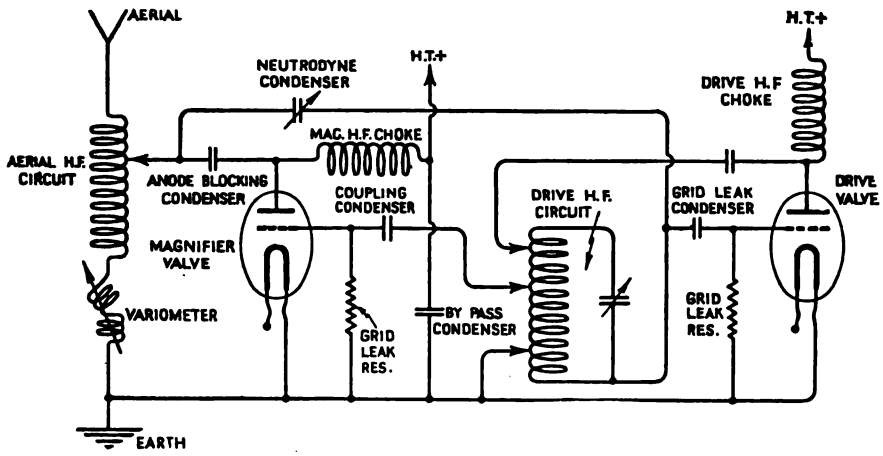

FIG. 2.

All machines are started by push button controls, the motors being usually designed to run on the standard ship's mains, with a total input of 9 to 10 kilowatts. With the regulator provided for the power alternator it is possible to obtain very fine regulation, from maximum power down to about 1/60th full power, the regulator being of the potentiometer type.

A suitable switchboard carries the necessary switches, meters and fuses for power, lighting, grid potentials and relay circuits. The machine regulators are also mounted here, the whole occupying only a small space.

A much simplified diagram of the high frequency circuits is shown above (FIG. 2).

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SHORT DISTANCE COMMUNICATION—II.

The Development and Performance of the S.A.1. Set.

In the October issue of the "Marconi Review" a technical description was given of a 7-8 metre combined transmitter and receiver—the S.A.1 set.

As both the receiver and transmitter are of unusual design, it was thought that an account of the development of the circuits employed would be of interest.

With a view to establishing authentic transmission range records, many range trials have been carried out with the S.A.1 set, and a detailed account of some of these are given in the following article, from which it will be seen that the apparatus is of a very dependable nature, and gives excellent results, and its guaranteed range is easily obtainable.

IT has been stated, in the case of the S.A.1 set, that as a general performance, using a half wave aerial, distances of 8 miles for Telegraphy and 6 miles for Telephony could be covered, whilst for the quarter wavelength aerial the figures were respectively 4 and 3 miles.

The difficulty of developing a set using frequencies of the order of 40,000 kilocycles to give a *guaranteed* performance such as is given above, can only be really appreciated by those who have undertaken a similar task. When it is considered that, in addition, this equipment has been developed for use by non-skilled personnel, and that the main essential before the designers has been the production of a set with the minimum of "knobs," the performance obtained becomes remarkable.

Without doubt, the S.A.1 set has no parallel in ease of working and adjustment, and the amazing facility with which the guaranteed ranges can be obtained by personnel with absolutely no prior knowledge of the apparatus places the set in the forefront of Military Equipments.

It is safe to state that the evolution of the set has demanded a series of building up tests which have far exceeded in time and number those of any kindred type of equipment.

The Development of the Circuits.

The possibility of the use of ultra-short wavelengths for military purposes was first conceived at the beginning of 1925. At that time the Marconi Company had developed the 6 metres revolving Beam as an aid to marine navigation, and it was principally from the success attending the use of this Beam system that the idea emanated of using similar circuits for military communications.

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Throughout 1925 development work was carried out at Croydon, and by November of that year the first experimental model had been completed; the circuits finally adopted embodied all the technical characteristics of the Beam transmitter and receiver, suitably modified for military purposes, and with the addition of Telephony.

Before, however, the equipment was placed on the market a complete series of range trials were carried out to determine exactly what performance could be expected under varying conditions of locality, screening, &c.

In general, the scheme adopted for these range trials was to place the transmitter at some predetermined position, and then to explore the surrounding terrain in all directions, carefully noting the effects of various distances and localities on quality, strength of signals, etc.

During these range trials a large number of demonstrations were given to various authorities, and in each and every case the results obtained were consistently good, and confirmed that in the S.A.1 set the Marconi Company had evolved an equipment which could be guaranteed to give 100 per cent. communication over the specified ranges at all times of the day and night, and in any locality.

Range Trials carried out near Croydon.

The locality in the neighbourhood of Croydon was especially suitable for carrying out tests of this nature, since, in certain directions, there are heavily wooded parts, in others, high ridges, and in others, localities completely covered with all forms of buildings.

A very great number of trials was carried out from time to time here, but the results may be summed up as follows:—

In whatever locality around Croydon the sets were tested on every occasion—whatever the screening, either due to trees, land or buildings—a range of 5 miles for telephony and 7 miles for telegraphy was obtained with ease, using half wave aerials at each end. As an example, it may be mentioned that on one occasion, when the car containing the "out" station was being repaired *inside* a galvanised iron garage, excellent communication was maintained over a range of 4 miles. In this instance the aerial was completely screened by a metal sheet within a few feet.

Ultimate ranges could not be worked in the direction of London, due to the difficulty of working in crowded city streets, but Fig. 1 shows the ground covered during the final trials.

The first position was in a small roadside clearing completely covered by trees, and with a high wire fence on one side. There was no overhead room to rig the aerial upright, but even with the aerial lying on the ground, signals, both on telegraphy and telephony were perfectly readable.

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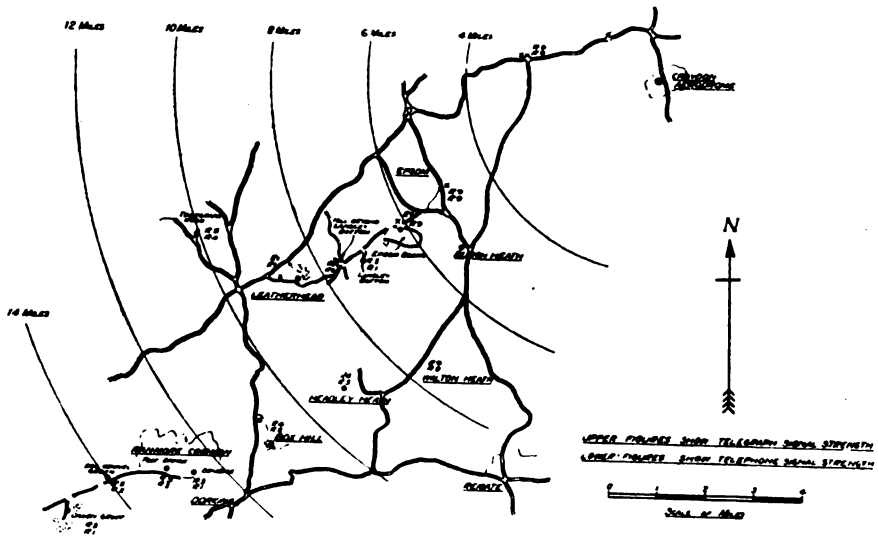

FIG. 1. *S.A.1. Range Trials around Croydon Aerodrome.*

In the next position, in a small wood just before commencing the climb to Epsom Downs, signals were R9. On Epsom Downs, which is high ground and 6½ miles from the transmitter, signals were very strong. The next position explored was the heavily wooded valley at Langley Bolton (7½ miles), and here speech was unintelligible, and Morse R3. On mounting the hill beyond the valley (8 miles), signals were again loud and clear, both speech and telegraphy.

It is interesting to note that on one occasion at this spot, a loud speaker was used direct with the receiver, and Morse signals could be clearly read at 44 yards from the receiver, and telephony 25 yards.

Approaching Leatherhead, a deep valley is reached. Here signals were only just audible, but about half a mile further I.C.W. signals were R5 and easily readable, speech being R4.

The next point was the top of Box Hill (11 miles). Telegraph signals were readable at strength R4, speech being only 50 per cent. intelligible. At a later date a further trial was made at practically the same position, but near trees, and no signals could be obtained. Two hundred yards away, in a clearing among the trees, signals were obtained R3.

At Ranmore Common (13 miles) telegraph signals were R3, whilst at the Post Office, half a mile further, signals had increased to R5, speech being R3-4.

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At Dog Kennel Green (14 miles) signals were about the same strength, and dropping down into the valley here, tests were made in the middle of a thick wood (15 miles) and to the general surprise, Morse signals were received R3.

At the next place, 16 miles, signals were inaudible. On other days tests were made at Headley Heath, Walton Heath and Burgh Heath, and various neighbourhoods around Warlingham and Sanderstead. In all cases signals were easily readable, and the effect of hills and valleys up to distances of 7 to 8 miles seemed to make little difference to signal strength.

Range Trials carried out over Sea and Land.

In order to determine the useful range of the S.A.1 set over water, arrangements were made with the kind permission of Trinity House Authorities to instal one set at the North Foreland Lighthouse and another on the T.S.Y. "Alert."

Preliminary tests were made in the neighbourhood of Blackwall Docks, and it was found that, despite the fact that in various cases there were very large masses of metal between the two sets, in the shape of steamers, dock buildings, etc., communication was *always* possible over distances of several miles.

At the North Foreland Lighthouse the half wavelength aerial was originally rigged on the seaward side of the light, whilst on the ship a half wave aerial was lashed to the stanchions of the deck above the Wireless Cabin, and some 20 feet from the funnel.

Various tests were carried out, which may be summarised as follows :—

Speech was always readable, whatever the position of the ship, up to distances of 16 miles, and was readable on occasions at 20 miles.

With the aerial on the lighthouse inside the building (the lighthouse is of stone and steel construction), and inclined at an angle of 70°, due to overhead steel beams, signals were received on the ship at 10 miles with perfect clarity. Morse signals were easily readable at 20 miles, and were heard at 22 miles with 6 miles of land intervening.

With the quarter wave aerial, speech was comfortably readable at 17 miles.

Experiments in turning the ship through a complete circle at 17 miles showed that for about five seconds, when the funnel was directly in a line between the two aerials, signals dropped to inaudibility, but placing the aerial on the opposite side of the lighthouse to the ship seemed to make very little difference to signal strength.

Fig. 2 shows the approximate course of the ship and strength of signals received at various distances.

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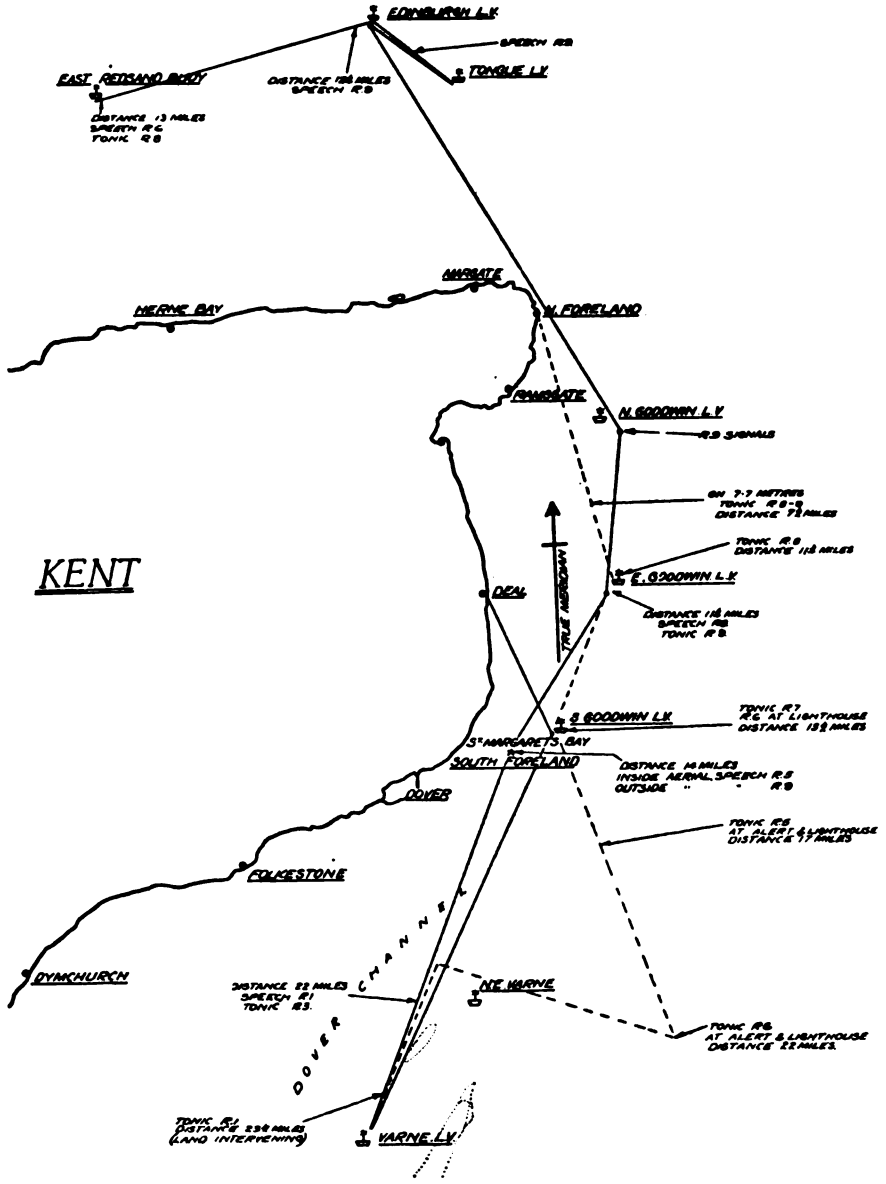

FIG. 2. *Chart of Trinity Steamer "Alert" during S.A.1 Range Trials.*

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Tests Abroad.

Since the S.A.1 set has been on the market a large number have been sold abroad, and reports received from time to time have confirmed the excellence of the results obtainable in even the most unskilled hands.

One interesting fact which has been commented on from several sources, is the extreme mobility of the set.

The following message, received from one of the users abroad, speaks for itself :—

> " It is worth mentioning that, taking the correct time at which the " station ceased working in any of the positions, it was observed that it " only required five minutes to pack, lift the set into the motor car, drive " two kilometres, erect the set and start a fresh communication. In some " instances only four minutes were required."

During trials in Spain, good signals have been received, all overland, at 26 kilometres.

The performance of the S.A.1 set under practical conditions as detailed above, combined with its stability, ease of handling, immunity from atmospherics and jamming, make it eminently suitable for the purpose for which it was designed—a hard wearing, extremely mobile and compact, foolproof set for military communications.

H. C. VAN DE VELDE.

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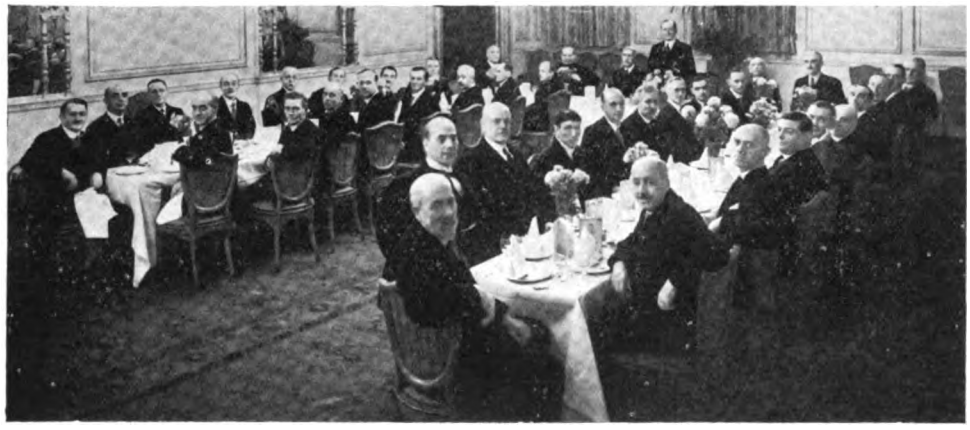
MARCONI NEWS AND NOTES

A MARCONI RE-UNION

A RE-UNION of old employees of the Marconi Companies as the guests of Senatore Marconi was held at the Holborn Restaurant on November 29th.

Every guest had been with one or other of the Marconi Companies for 25 years or more, and 40 of the 47 persons having this qualification were able to be present.



Among the guests were Colonel H. Jameson-Davis, the Founder in 1897 of the original Company, then known as the Wireless Telegraph and Signal Company, and Dr. J. A. Fleming, F.R.S., who has been associated with the Company almost from its inception. Additional interest attached to the presence of Dr. Fleming who was also celebrating his 79th birthday.

After the toast of "The King," Senatore Marconi proposed "The Old Brigade." He referred to several of the very early tests; the watch-keeping on the East Goodwin Light Vessel; the tests across the Atlantic when the first signals were received, and mentioned the names of a number of men who took part in them, several of whom were present that evening; he spoke of the many Operators who did their work so nobly during the War, members of a body who at all times are liable to be called upon as a consequence of their special duties to live up to a great tradition of service. He congratulated his guests on having stayed the course so long.

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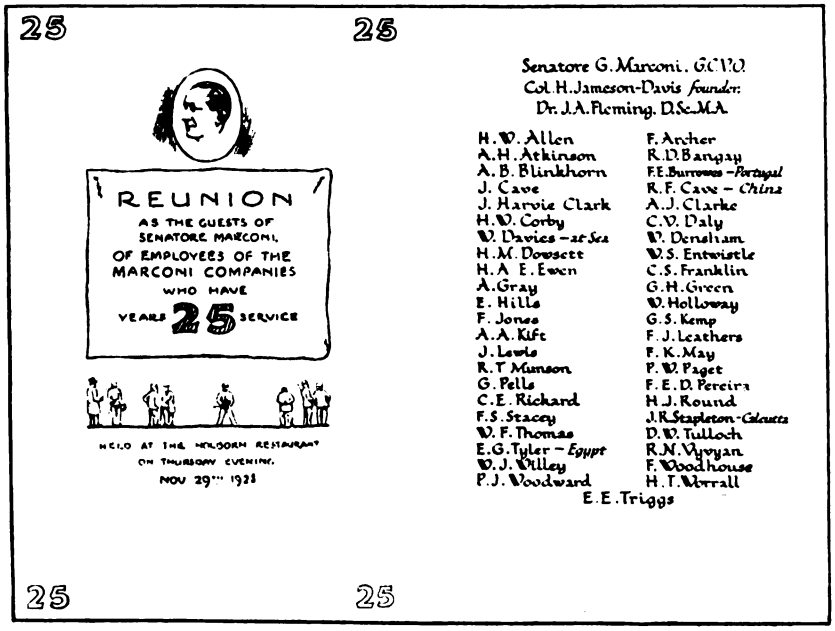

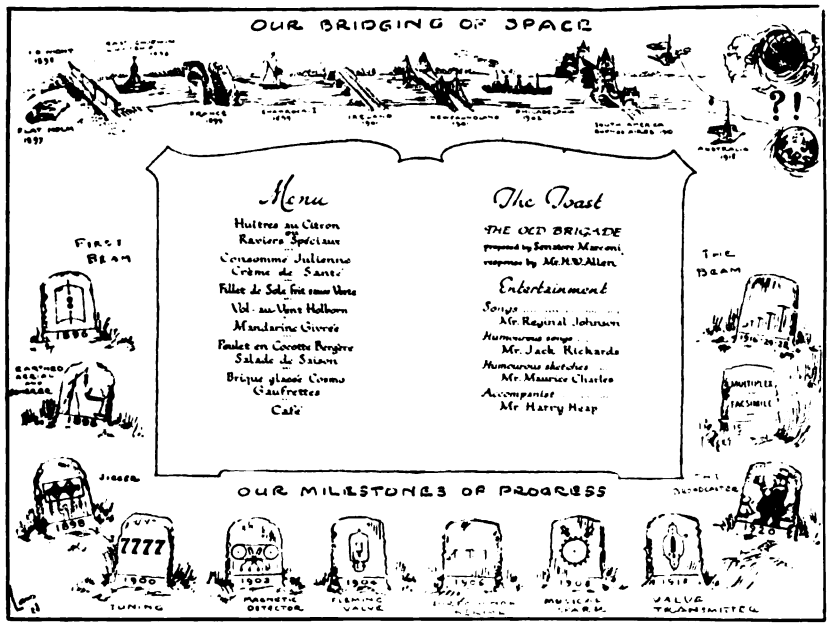

The Menu Card.

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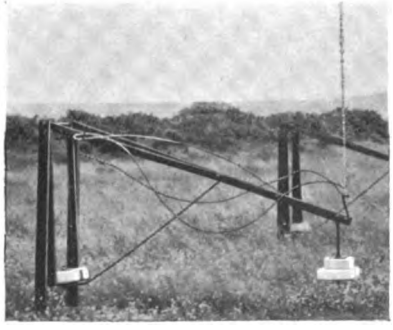
Mr. H. W. Allen, the first Secretary of the parent Company, responded. Short speeches were also made by Colonel Jameson-Davis, Dr. Fleming, Captain Daly and Mr. G. S. Kemp, who reminded his audience that the 29th November was also the anniversary of the erection of the mast at the Needles, Isle of Wight, which was the first Wireless Station to be installed in Great Britain.

Mr. Andrew Gray proposed that the present gathering should inaugurate an annual function at which Senatore Marconi, instead of being the host, would be an honoured guest. This was unanimously agreed to with acclamation, and after a vote of thanks to the Honorary Secretary, Mr. C. E. Rickard, who on behalf of Senatore Marconi was responsible for all the arrangements, the proceedings terminated.

The Menu Card, which is here illustrated, was in the nature of a surprise for the guests, to whom it will be an interesting souvenir.

Under the inspiration of Mr. Rickard, Mr. W. J. Laws, artist, and Mr. L. H. Blouet, photographer, had illustrated on the card some twelve " milestones of progress " in the development of wireless technique achieved by Senatore Marconi and his associates, from the first reflector tests carried out in 1896 to the Beam Stations of the present day. This feature was supplemented by another series of drawings illustrating the progressive conquest of space by a parallel development in bridge-building, from the simple foot-bridge spanning a stream, to a rope-way with a carrier where the distance was too great to be spanned by any other means. This series ends with a problem—Can we communicate between the Earth and Mars ?

Beam Aerials withstand Worst Gale for 30 Years.



Balance weight and check wire.

The Marconi Beam aerial system has been specially designed to withstand the severest weather conditions, and during November all the English Beam stations were put to the most severe test during a hurricane which swept over the country and which was described as the worst gale for 30 years.

At times the wind, in certain places, reached a velocity of 120 miles per hour and, in addition to extensive damage to property, hundreds of trees and telegraph and telephone poles and wires were hurled to the ground, thus throwing landline communication into disorder.

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Notwithstanding the severity of the gale, however, the safeguarding apparatus of the Beam aerials fulfilled its function and the Beam stations escaped without damage.

In order to keep the aerial and reflector wires of the Beam stations taut under varying wind pressure, they are suspended from triatics slung between the masts on a double catenary system, so that there is hardly any movement at the top of the wires. The lower ends of the aerial and reflector wires are attached, by means of insulators and short lengths of chain, to safety hooks fixed to the arms of the balance weights. When the windage on the wires increases the weights gradually rise to keep the load approximately constant. If the wind increases further, at a certain value the arm of the balance weight rises to a position in which the hook is automatically opened, thus releasing the aerial wire. The balance weight then comes to rest on the ground, and the wires are prevented from flying away by a check wire attached to the chain and to the balance weight. In this way any excessive load on the triatics and masts is released, and when the strength of the wind is reduced all that has to be done is to restore the wires to their respective hooks.

In the recent storm, the most serious that has yet been experienced since the Beam stations have been in operation, this safety device worked perfectly. In every case of which we have record the landlines serving the wireless stations were interrupted before the aerial wires were released. It was expected that when the wires were released communication would be interrupted, but experience has proved that the aerials, though loose, retain their general formation and communication can be maintained.

Air Telephony Records.

A message recently received at Croydon Aerodrome from the R.A.F. wireless station at Cairo states that telephone conversations sent out by an air liner which was carrying out tests with a Marconi short-wave experimental telephone transmitter while flying over England were distinctly heard in Cairo.

This is a world's record in long distance telephone transmission from an aeroplane in flight, the distance from Croydon to Cairo being some 2,000 miles. The feat is the more remarkable because the power used by the aeroplane was only in the neighbourhood of 50 watts.

A previous Marconi record was achieved as long ago as June, 1923, when the late Captain Hinchcliffe, the famous British air pilot, using a standard Marconi A.D.6 transmitter of 150 watts power, spoke to Croydon by wireless telephone while flying near Bremen, Germany. The distance covered on that occasion was 400 miles.

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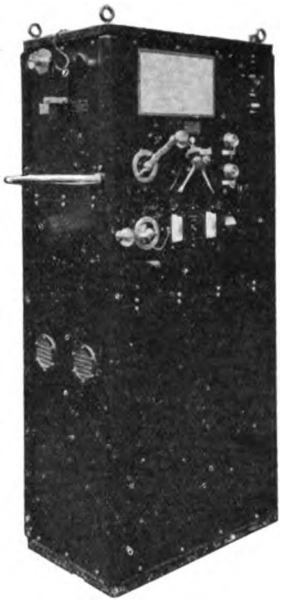
Wireless Apparatus for Whalers and Trawlers.



Type XMC1.

During the last two or three seasons, Marconi apparatus has played an important part in the whale-catching industry in the Antarctic. The fleet of the Southern Whaling and Sealing Company has been equipped with specially designed Marconi telephone apparatus to enable the whale catchers and the factory ships to keep in constant touch with each other and with their base at Prince Olaf Harbour, South Georgia, where a Marconi land station has been erected.

The telephone sets on board the whalers have been designed for operation by totally unskilled persons, and to withstand the hardest usage. They are in fact usually worked by the gunners, and in view of this arrangement are made for loud speaker reception so that the gunner need not remove his heavy head-dress in order to carry on a conversation with other members of the fleet. The whalers have found that astounding results and record seasons have followed the use of the wireless telephone, which enables the closest co-operation to be maintained between the various units of a fleet.

Previously, several vessels of one fleet might search for days without sighting a whale while another found more than it could cope with alone. It is now a simple matter for all the vessels to work together and in consequence a wider ground is covered and greatly increased catches have been obtained.

Similarly, deep sea fishing fleets are being equipped with Marconi telephone apparatus to enable whole fleets to take advantage of the best fishing grounds and to keep in touch with their owners so that landing arrangements can be made to take the greatest advantage of prevailing market conditions.

Apart from the commercial value of wireless communication to whalers and fishing vessels, it is of proved utility to the safety of life and property at sea. As an instance of this may be cited the case of a whaler which broke down with four whales made fast alongside when far out at sea, through engine trouble. The wireless telephone set installed on board the whaler enabled the gunner to communicate with another whaler which immediately proceeded to his assistance and towed the vessel and whales to land, thereby averting great hardship to the crew and the loss of many thousands of pounds by the whaling company.

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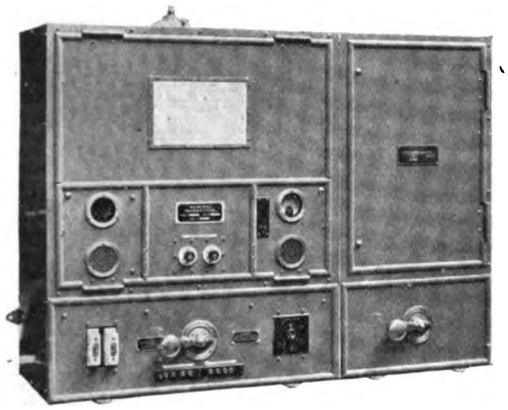
In another case a steam trawler, returning home from Greenland, crashed into an iceberg during dense fog. Within a few minutes the damaged vessel was in telephone communication with a sister ship which came up and stood by as a precaution. Fortunately, although badly damaged, the injured vessel was able to proceed under her own steam, but she was accompanied by her sister ship across the Atlantic.

The Marconi telephone sets specially designed for use by unskilled persons under such conditions as those prevailing on whalers and fishing vessels are the type XMC1 of 500 watts power, the type XMD1 of 250 watts power, and the type XMB1 of 100 watts power. The transmitting and receiving units are totally enclosed in sheet steel cabinets. The wavelength for the required service is fixed beforehand, and there are none of the usual adjustments to be made. All that the operator has to do in order to carry on a conversation is to switch over a send-receive lever.

For Island Communication.



Type XMD1.

Quite apart from their value for service at sea, as shown above, this type of Marconi apparatus is of great value for land stations. It is being used by the British General Post Office in connection with a scheme which has been receiving the careful consideration of the authorities for some time past for the purpose of linking up outlying islands with the British mainland owing to the expense, in these circumstances, of maintaining cables which are frequently broken by the tide.

Two XMD1 stations, which can be used for communication either by telegraphy or telephony, have been erected at Loch Boisdale and Tobermory in the Hebrides to ensure communication with the mainland in the event of cable breakdown.

It is confidently expected that, owing to the successful operation of these stations, other stations included in the scheme will be fitted with this type of apparatus in due course.

At Alderney and Guernsey, in the Channel Islands, XMB1 sets have been installed, their purpose being to augment the service of the cable between the islands and, in time perhaps, to displace it altogether.

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Marconi Wireless Telephone Equipments.

Marconi wireless telephone installations are proving of the greatest value for communication between scattered posts, in oil fields, ranches, and other similar undertakings in all parts of the world.

The following is an extract from a letter accompanying an order on Marconi's Wireless Telegraph Co., Ltd., for five wireless telephone stations, types XMC1 and XMD1, together with the Marconi Automatic "Call."

> "We thank you for the prompt and helpful advice which you have given "us in connection with this matter, as has been the case in our past dealings "with you.
>
> "It was, as you will understand, with some misgivings that we entered "upon the experiment of using wireless telephony on our oilfields, but the "experiment has more than justified itself, and this has been in no small "measure due to the satisfactory service which the apparatus supplied by "your Company has given."

The Company has previously supplied this customer with ten stations of various types, and these have now been in constant use for a considerable time.

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No. 4

THE MARCONI REVIEW

January, 1929

CONTENTS

THE INFANT HERCULES - - - -	PAGE	1
THE MARCONI-WRIGHT FACSIMILE SYSTEM -	„	5
THE DESIGN OF TRANSMITTING AERIALS FOR BROADCASTING STATIONS - - -	„	7
MARINE DIRECTION FINDERS. TYPES 11G. AND D.F.M.3 - - - - - -	„	16
LONG AND SHORT WAVE COMMERCIAL RECEIVERS - - - - - - -	„	21
NOTES ON BROADCAST TRANSMISSION - -	„	27
MARCONI NEWS AND NOTES—		
THE PHYSICAL SOCIETY AND OPTICAL SOCIETY EXHIBITION - - -	„	30
WIRELESS APPARATUS FOR HARBOUR WORK - - - - - - -	„	31

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD.

Marconi House, Strand, London, W.C. 2

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THE MARCONI REVIEW

No. 4. *January, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

THE INFANT HERCULES

A REMARKABLE CARTOON

A LITTLE more than 25 years ago, on the 30th March, 1903, *The Times* published the first transatlantic Marconigram, and *Punch*, true to its reputation for interpreting the public opinion of the day, signalised this event in its issue of the 15th April, 1903, by the cartoon which is reproduced on the next page.

It symbolises something more than the potentialities of a new invention; the sturdy virile growth of the Infant Hercules, nurtured by science and cradled in the Marconi Company, suggests that with the vision of the inventor is associated constructive ability, and a dynamic organisation capable of consolidating development and marking out a clear line of irresistible progress, cleaving a way between the Government Land Telegraphs and the well established interests of the Ocean Cables, the two recognised means of signalling which up to that date had divided the communications of the whole world between them.

In the old Greek legend Hera sent two serpents to destroy the new-born Hercules, but he overcame and strangled them.

Needless to say the artist did not intend the analogy to be taken too literally; at no time has any one of the protagonists been in danger of extermination at the hands of one of the others, the aggressive enterprise of wireless being countered by an improved public service and attempts at restrictive control, proposed and supported by the established systems, and as each possesses a sphere of operation in which the others cannot encroach, the healthy rivalry engendered has resulted in the steady but hard won progress of wireless and a gain to the communications of the Empire considered as a whole, and of the world in general.

Bearing this in mind, it may be worth while to recall the events which made Wireless history about the year 1903 and thereby gave rise to this cartoon.

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Following the preliminary trials across the Atlantic on December 12th, 1901, the possibility of establishing effective communication was placed beyond doubt by authenticated tape records obtained on the S.S. Philadelphia during Mr. Marconi's next voyage to the United States in February, 1902, and the general public then began to realise that the cable companies had a live competitor.

Other long distance tests followed. Signals were received from Poldhu on the Italian cruiser Carlo Alberto at Kronstadt in July, at Spezia in August, and across the Atlantic at Sydney, Nova Scotia, in October.

The station under erection at Cape Breton was far enough advanced for an inaugural message to be sent by the Governor-General of Canada to King Edward VII. and to the King of Italy on December 21st, 1902, and on January 19th, 1903, the President of the United States, Mr. Roosevelt, sent a message of greeting to King Edward through the newly completed station at Cape Cod. At length, greatly daring, the Marconi Company opened a limited public service across the Atlantic, the first paid news message being sent to *The Times* on the 30th March, 1903.

For a few months there was a rush of messages to and from Canada and the United States, and then both services were brought to a temporary standstill by plant failures, transatlantic wireless telegraphy in its early stages being no less subject to interruption than was transatlantic cable telegraphy at the beginning of its career.

Turning now to another branch of wireless development, that of ship to shore telegraphy, in the year under review, the Marconi Company having installed apparatus at several signal stations belonging to the Corporation of Lloyds, was working through coast stations at Caister, North Foreland, Niton, The Lizard and Holyhead in England; Malin Head, Rosslare and Crookhaven in Ireland; The Nantucket Light Vessel, Babylon and Sagaponak in the United States; and conducting a successful public service to numerous ships of various nationalities equipped with Marconi apparatus, the first British Merchant ship to be fitted being the ss. Lake Champlain, on the 21st May, 1901.

The Company had evolved a system of wireless telegraphy applicable to the ships of all nations, so that in case of distress they could inter-communicate and co-operate with one another. The organisation which had been created to operate the instruments and handle and clear the traffic was working efficiently, and the system of accountancy which had been devised to cover the prepayment of messages on board ship to destinations in various countries having their own land charges—through rate cards being introduced in 1902—had solved a very important problem, and allowed the traffic to be handled on practical business lines.

In the United Kingdom messages for ships were addressed to the Marconi

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PUNCH, OR THE LONDON CHARIVARI.—April 15, 1903.

THE INFANT HERCULES.

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station, and those received from ships were sent to the local post office either by hand, or at a later date they were transmitted by private wire.

The British Post Office, while it possessed a monopoly of all communication by land line telegraphy, had no power of control over the transmission of ether-borne messages. It was not until August, 1904, when the Wireless Telegraph Act was passed, that it became the supreme authority in this country.

The first International Conference on Wireless Telegraphy for the regulation of the use of Wireless at sea was held in Berlin, in the month of August.

In other directions development work was yielding useful results. Tests carried out in March, 1903, between Poldhu and The Lizard, had shown that with two transmitters working 100 yards apart, one on a transatlantic wave and the other on a ship wave, the signals could be received on one aerial and separated out by means of two tuned receivers, and this led to the introduction of the long distance Press service to ships at sea by transmission from Poldhu, which started on August 18th, 1903.

The account of the year's work would not be complete without a reference to the co-operation which existed between the British Admiralty and the Marconi Company, which led to a new and more complete agreement being concluded in July, 1903, in place of the limited agreement for the supply of wireless apparatus to the Navy, entered into in 1901, and to a demonstration being given in October, 1903, of the use of long distance transmission to the Fleet during the voyage of H.M.S. *Duncan* to the Mediterranean with Captain Jackson representing the Admiralty and Mr. Marconi on Board.

Undoubtedly 1903 was a notable year in Wireless history.

Coming now to our own time and the subject of this article, with the passage of more than 25 years, the Wireless Hercules has attained maturity. Channels of communication straddle the earth and reach out to the mobile ship, the aeroplane and even the submarine.

Land line telegraphy and telephony have, in the interval, learnt much from Wireless, and valve amplifiers and carrier wave methods are now common to both. The close association which is commencing between Wireless and the Cables gives to the *Punch* cartoon another meaning, which is the reason for its reproduction here, the entwining of the three systems being from the new point of view one of affinity in service with a difference of function, such as should enable all the needs of world communications to be most effectively met.

H. M. D.

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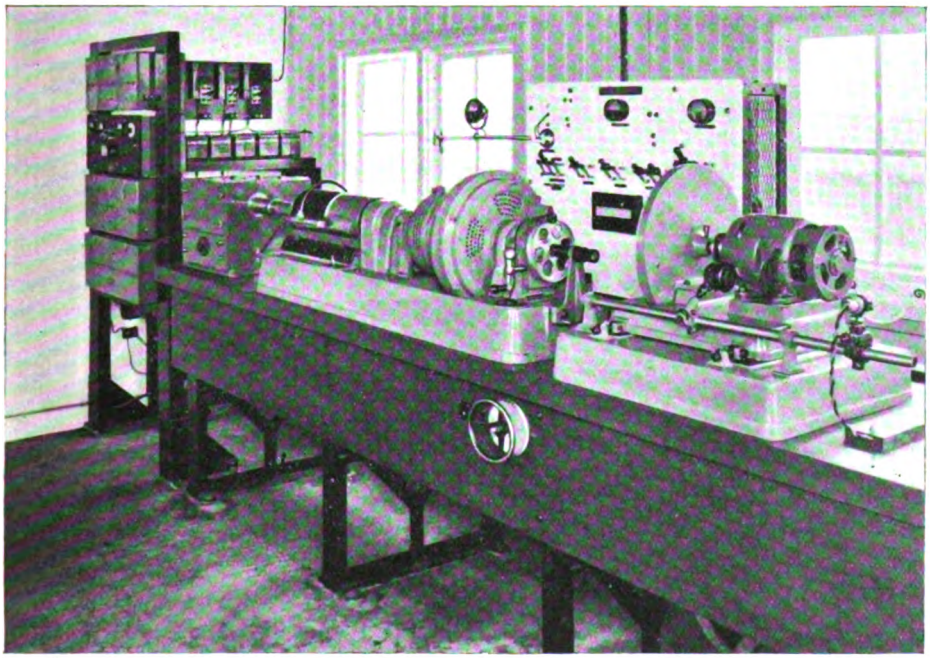
MARCONI-WRIGHT FACSIMILE SYSTEM

PRESENT POSITION OF DEVELOPMENT

FACSIMILE transmission, or the accurate high speed transmission of print, pictures, finger-prints, etc., by land line or by wireless telegraphy, has a very wide field of application for general communication purposes, and in particular for press work.



As distinct from "picture telegraphy," it provides a more exact reproduction of the original than that which is necessary to satisfy the usual light and shade requirements of a picture.

For several years past high speed facsimile transmission has been the subject of extensive research work, but it was only as a result of recent developments that it could be said to have reached the stage which ensures commercial success.

The apparatus which the Marconi Company is now placing on the market is very dependable, speedy, simple to operate, and when used on a Post Office land line of good quality, gives excellent reproduction.

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The same type of apparatus has for some months been employed on short wave wireless experimental transmission of facsimile between the United States and England, and, under suitable wireless conditions it has given very satisfactory results.

It is found, however, that short wave transmission of facsimile over great distances is less satisfactory than over a good land line, due, not to any defect in the apparatus, but to distortion effects which are produced in the radiation as it passes through the medium between the two stations. The research engineers of the Marconi Company are now concentrating their efforts to overcome the difficulties introduced by this new factor.

These transatlantic tests should not be confused with the commercial service employing the Ranger system, which has been in operation now for two and a half years and giving good results. This is a slow speed method, and has been confined to long wave working.

The illustration gives a comprehensive view of the Marconi-Wright facsimile apparatus at the transmitter end. The apparatus on the right shows the chopper disc and driving motor, with controlling switch board for the whole apparatus. In the centre is the optical rotor and lens system, and on the left are the amplifiers, etc., mounted in box form on a frame.

A potassium argon light cell is used at the transmitter end in the Marconi system, and a Kerr cell at the receiver end.

A complete description of the apparatus will be given at a later date, in THE MARCONI REVIEW.

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THE DESIGN OF TRANSMITTING AERIALS FOR BROADCASTING STATIONS*

By Capt. P. P. ECKERSLEY & H. L. KIRKE,
of the BRITISH BROADCASTING CORPORATION, *and*
T. L. ECKERSLEY, B.A., B.Sc.,
of the Research Department MARCONI'S WIRELESS TELEGRAPH COMPANY.

This paper deals with an important technical aspect of the problem of transmitter design—the design of the transmitter aerial. If this matter is dealt with scientifically, and the recommendations are followed by Continental organisations, something might be done to improve the service to European listeners. The proper method of attack against the problem of mutual interference between stations and the all too limited service area of stations is to attempt to design an aerial so as, ideally, to make it a radiator which only produces a direct ray or ground ray, i.e., a ray initially parallel to the earth's surface. It is the existence of the indirect ray which produces all the difficulties inherent to the production of a good broadcasting service, not only because such an indirect ray interferes with other very distant stations, but also because it produces fading and bad quality in the local service area. Further, all energy radiated upwards is, in broadcasting, lost energy.

Obviously the more an aerial can be made to radiate only in a direction tangential to the earth's curvature at the base of the aerial, the more the ideal conditions will be approached. If all the aerial energy could be directed to produce this type of radiation there would be no indirect ray, no fading of signals, less interference with certain other stations at night, and greater power efficiency of the aerial. Certainly we might expect some interference, but at a skip distance, not everywhere as at present. Thus it is important for broadcasting engineers to consider the aerial only in regard to its ability to produce radiation normal to its vertical portion. It is further important, however, to enable an engineer to specify the extent of service area, to know the rapidity at which these rays will be attenuated. This paper thus deals, in the second section, with considerations of attenuation, and gives a complete set of attenuation curves for various broadcasting wavelengths.

Theoretical Considerations of Aerial as Radiator.

THE behaviour of a high aerial situated on a perfectly conducting earth is well known, and has been fully worked out by Stuart Ballantine. In any actual case, however, the earth's resistivity has to be taken account of. One of the writers has concluded, on the basis of Sommerfeld's analysis of the case, that the behaviour of an aerial situated on ground of conductivity σ differs only slightly from this ideal case when the conductivity is so large that $\sigma\lambda c$ is large compared with K, the specific inductive capacity of the earth.

The effect of the finite conductivity of the earth is as if a constant small resistance Ro, independent of the height of the aerial, were added to the radiation resistance calculated in accordance with the ideal case. We are therefore justified in using Stuart Ballantine results if due attention is paid to the extra resistance on account of earth loss.

* Summary of paper read at a meeting of the Wireless Section of the Institution of Electrical Engineers, on 18th Dec., 1928.

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One aspect of these results is illustrated in Fig. 1, where the polar diagrams (in the vertical plane) of a $\frac{1}{2}$ wave aerial and one small compared with $\frac{1}{4}\lambda$ are shown. These are drawn for the same metre-amperes in the aerial so that the field strength in the horizontal plane is the same in the two cases. It is obvious from a direct inspection of the figure that the directive efficiency in the horizontal plane is much greater for the $\frac{1}{2}\lambda$ than the $\frac{1}{4}\lambda$ or small aerial. The latter wastes much of its energy by upward radiation, which is not present in the case of the $\frac{1}{2}\lambda$ aerial because of the phase cancellation of the radiation from the widely separated elements of current in this aerial. It is obvious from this figure that a given signal strength can be obtained with much less input power with a $\frac{1}{2}\lambda$ aerial than with a $\frac{1}{4}\lambda$ aerial, say. Fig. 2 shows the relative power necessary to produce a given signal strength as a function of the height of the aerials. The higher the aerial up to $\lambda/2$, the less the power. These curves are given for various dead loss resistances. It is important to realise that the gain of a $\frac{1}{2}\lambda$ over a $\frac{1}{4}\lambda$ aerial is almost independent of this resistance so long as this is small, compared with the 100-ohm. radiation resistance of the $\frac{1}{2}\lambda$ aerial. The results to be expected from an experimental test are therefore confined to fairly narrow limits, and a good confirmation of the theory will be obtained if the results are within these limits.

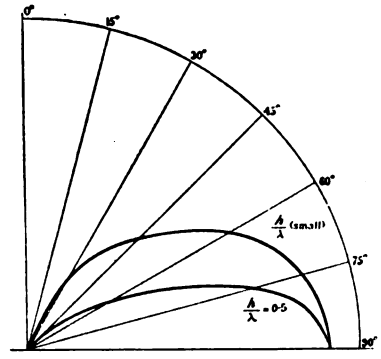

FIG. 1. — *Vertical polar diagram of radiation for $\frac{1}{2}\lambda$ and $\frac{1}{4}\lambda$ (or less) aerials. Drawn for the same maximum radiation intensity in the horizontal plane.*

It will be seen that the reduction in high angle radiation occasioned by the use of a $\frac{1}{2}\lambda$ aerial should reduce fading.

Experimental Tests.—It was thought important to test this theoretical analysis in terms of full-scale experiments. To this end the British Broadcasting Corporation approached the Air Ministry with a view to hiring a captive kite balloon to support various lengths of aerials.* The site of the experiments was Larkhill, near Amesbury, on Salisbury Plain.

The first experiment was to determine whether, for the production of a given field strength, the necessary power in the aerial was decreased, as theory indicated, by changing from a $\frac{1}{4}\lambda$ to a $\frac{1}{2}\lambda$ vertical aerial.

* The authors' most grateful thanks to the Air Ministry are expressed more fully in the conclusion to the paper.

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Difficulty was at first experienced in the mechanical arrangement for supporting the vertical wire of the aerial, but the final scheme adopted was to attach the earth end of the aerial wire firmly to an anchor on the ground, while 60 ft. of rubber shock-absorber was interposed between the balloon and the free end of the aerial.

The power was fed in from the B.B.C. transmitting lorry, which contains a 1 kw. valve transmitter, the power being derived from an alternator clamped to the chassis and driven by the engine of the lorry.

The earth for the aerial consisted of 40 wires radiating from a point immediately under the aerial, each wire being 250 ft. long, and buried in a plough furrow about 6 in. deep.

In order to take account of changing winds the lorry carrying the winding gear for the hauling up and down of the balloon was moved from place to place.

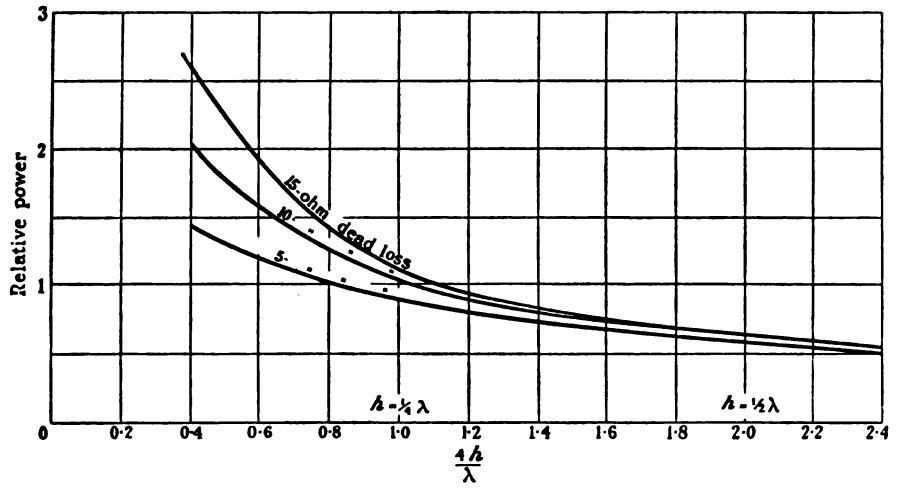

FIG. 2.—*Relative power required to produce a given value of metre-amperes.*

To leave no doubt as to the results, the usual wire hawser for the captive balloon was substituted by a hempen rope. No one made the ascent in the balloon, which was, as a matter of fact, condemned for purely service conditions.

It will be appreciated that one of the greatest practical difficulties was to take accurate readings of the current in the $\frac{1}{4}\lambda$ aerial, as the maximum current occurs half-way up the aerial. Specially large ammeters were, however, constructed, and the readings were taken by telescope.

It was most unfortunate that after the first week the unusually fine weather broke. Great difficulty was experienced due to gales of wind, and a great deal of the time was wasted in waiting for " flying weather." On one occasion the whole rigging collapsed.

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Method of Measurement of Constants of Aerials.

Power.—It was essential to have an exact knowledge of the power in the aerial. For the $\frac{1}{4}\lambda$ aerial this was obtained as follows :—The circuit and current distribution were as shown in Fig. 3. The voltage (V) between aerial and earth and the aerial current (I) were measured at various frequencies, and Z, the impedance, was taken to be V/I. The aerial was said to be in tune when Z was a minimum. The power in the aerial was then $Z_{\frac{1}{4}\lambda}I^2$. For the $\frac{1}{2}\lambda$ aerial the connections were as shown in Fig. 4. Z was again compared with frequency, and the aerial was said to be in tune when Z was a maximum. The power in the aerial was in this case the square of the current I_a at the base of the aerial multiplied by the total impedance, $Z_{\frac{1}{4}\lambda}=V/I_a$ (where $Z_{\frac{1}{4}\lambda}$ is a maximum).

Field Strength.—The field strength was taken as the average of six measurements at different points on a circle around the aerial. Each reading was taken at 2 km. from the aerial. The results are given in tabulated form on page 13.

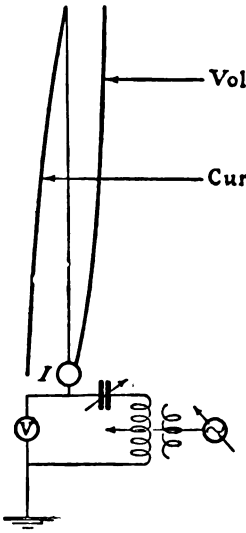

FIG. 3.

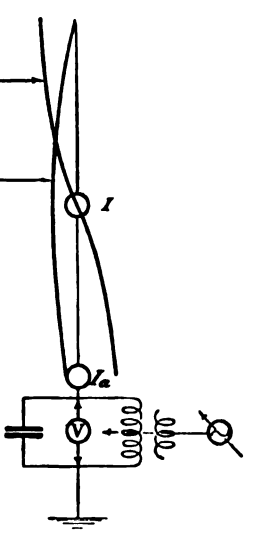

FIG. 4.

Observations on the Results.

General.—Assume the aerial in both cases to have a 10-ohm dead loss. It is not an unlikely figure, and it is perfectly just to assume the same loss in both aerials, the major loss in any aerial system being due to the field intensity around the aerial. It will then be seen (Fig. 2) that the ratio of power with $\frac{1}{4}\lambda$ to $\frac{1}{2}\lambda$ aerials to produce a given field strength with a 10-ohm dead loss is theoretically 1/0·61 and in the practical measured case 1/0·625—a remarkable confirmation if a 10-ohm dead loss is a fair assumption. Putting the matter still more generally, it can be seen that at any rate there is a substantial gain in the use of $\frac{1}{2}\lambda$ aerials.

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Attenuation.

The second factor in the determination of the broadcast performance of a given transmitter is attenuation. Deviations from the ordinary Hertzian formula for transmission over a perfectly conducting plane are occasioned by the imperfect conductivity of the earth.

These deviations are taken account of in Sommerfeld's formula, some of the implications of which are discussed in this paper. In particular, it is shown that the attenuation curve for any wavelength may be derived by a geometrical construction from the observed curve on some standard wavelength, say.

The effect of the earth's conductivity enters into the attenuation formula, though the quantity $d_n = \frac{\pi x}{\lambda} \frac{1}{2\sigma\lambda c}$, which Sommerfeld calls the numerical distance, and the curve (Fig. 5) is useful in representing the factor by which the Hertzian formula must be multiplied in order to give the actual signal strength as a fraction of d_n which contains the unknown quantity σ. Experimental tests to determine this, to test the Sommerfeld formula, and to determine the family of attenuation curves, were carried out by the B.B.C.

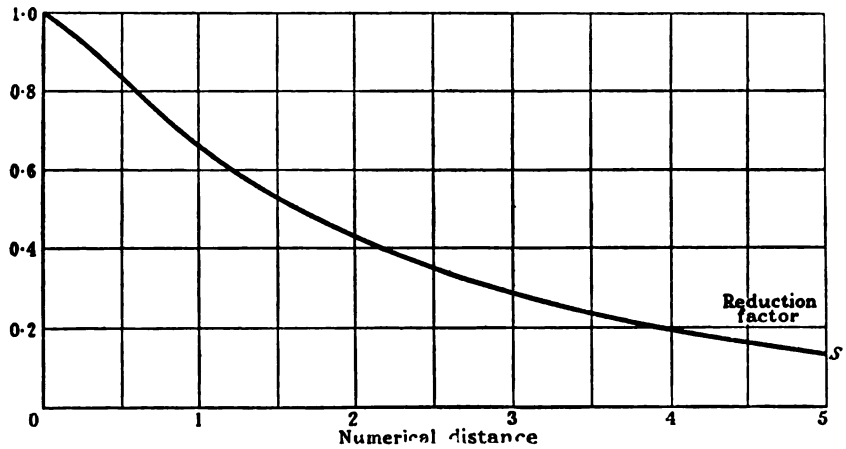

FIG. 5.—*Sommerfeld's Theory.*

Experimental Tests.

The British Broadcasting Corporation undertook to attempt to find in a given territory attenuation curves for all frequencies of emission between 500 and 1,500 kilocycles per second. To this end a site was chosen (which will ultimately become the site of the London regional transmitter) near Potters Bar, on the north side of London, for the erection of an aerial, the radiation from which could be measured in terms of field strength up to a distance of 100 km. The aerial consisted of 95 ft. of vertical wire, and was of the same form for all wavelengths. The masts were 110 ft. high, and were placed 300 ft. apart, and their base and the stays were insulated from the ground.

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Tests made near to the aerial showed that radiation was strictly equal in all directions.

In effect the method of procedure was to adjust the current in the aerial so that the field strength was the same whatever the frequency of emission at the same point close to the aerial. This meant that the term $h_1 I/\lambda$ was adjusted to be the same for every wavelength. We can thus say that the curves are taken for the same radiated power at all wavelengths. It was seen that the points do not lie by any means on a smooth curve. Intelligent interpolation, however, gave a family of smooth curves for two directions.

The difficulty of taking readings in a densely populated country such as that found around London cannot be exaggerated, and the authors feel somewhat diffident in placing too much reliance upon the results. At points a few wavelengths apart, the field strength may vary 50 per cent., even though care is taken to avoid the proximity of telephone wires, houses and trees.

An experimental test of the geometrical construction for transferring the results of one wave to another, showed a very fair agreement between observation and theory, confirming the validity of applying Sommerfeld's analysis to this case.

We have so far considered the experimental verification of the theory of transference of the points from one curve to another for different *wavelengths*. It is also important to see whether the theory of transference of points for different values of σ is correct in practice. Although not a great deal of accurate experimental data is available, it is nevertheless interesting to consider the question of the value of σ, the earth's conductivity, as derived from the experimental results. An analysis can be given as follows :—

Any two transmitters having the same value of $h_1 I/\lambda$, *i.e.*, the same metre-amperes factor, can be said to be similar transmitters, and we can therefore write

$$\frac{377\, h_1 I}{\lambda} = B \text{ (a constant)} \qquad .. \qquad .. \qquad (2)$$

therefore $E_o = (B/x)\, S$, where x is the distance of the point of measurement from the aerial.

If there were no earth losses and other losses on the surface of the earth due to houses, trees, etc., the field strength would be given by $E_o = B/x$.

The multiplier S can therefore be called the reduction factor, and is shown by Sommerfeld to be a function of the quantity d_n, the numerical distance, where $d_n = (\pi x/\lambda)\{1/(2\sigma\lambda c)\}$ (see page 11).

Fig. 5 gives the relation between S and d_n, and is derived from the Sommerfeld theory. It is now our object to test the accuracy of the Sommerfeld attenuation formula and to determine the necessary value of σ.

Take the mean attenuation curves mentioned above. With $x = 60$ km. and $\lambda = 248$ m., $E = 0{\cdot}63$ mv./metre. Since these curves are for a radiated power of 1 kw., E_o, the field strength apart from attenuation, will be given as

$$E_o = \frac{377\sqrt{\left(\frac{1{,}000}{1{,}580}\right)}}{x} = 5 \text{ mv./metre}$$

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Experimental Tests.

Type of aerial, h/λ	Height of aerial, h	Wave-length, λ	Voltage (V) between base of aerial and earth	Current at base of aerial (I_a for $\frac{1}{4}\lambda$ aerial)	Aerial current I (max. current in aerial)	Impedance: $\frac{1}{4}\lambda$ aerial, $Z_{\frac{1}{4}\lambda} = \frac{V}{I}$	Impedance: $\frac{1}{2}\lambda$ aerial, $Z_{\frac{1}{2}\lambda} = \frac{V}{I_a}$	Power in aerial: $\frac{1}{4}\lambda$ aerial, $W = Z_{\frac{1}{4}\lambda} I^2$
	metres	metres	volts	amp.	amps.	ohms.	ohms	watts
$\frac{1}{4}$	70	288·5	108	—	2·6	41·5	—	281
$\frac{1}{2}$	140	288·5	1,350	0·375	2·1	—	3,600	—

Type of aerial, h/λ	Power in aerial: $\frac{1}{4}\lambda$ aerial, $W = Z_{\frac{1}{4}\lambda} I_a^2$	Field strength, E, at 2 km.	Effective height (practical), $h_1 = \frac{E\lambda d}{377\,I}$	Effective height (theoretical), $h_1 = \frac{2}{\pi}h$	Radiation resistance: $\frac{1}{4}\lambda$ aerial, Practical, $R_R = \frac{A_3^* h_1^2}{\lambda^2}$, where $h_1 = \frac{E\lambda d}{377\,I}$	Radiation resistance: $\frac{1}{4}\lambda$ aerial, Theoretical, $R_R = \frac{A_3 h_1^2}{\lambda^2}$, where $h_1 = \frac{2}{\pi}h$	Radiation resistance: $\frac{1}{2}\lambda$ aerial, Theoretical, from Fig. 2	Total resistance, $R_T = \frac{W}{I^2}$
	watts	mv./metre	metres	metres	ohms	ohms	ohms	ohms
$\frac{1}{4}$	—	64	38	43·5	27·5	35	—	41·5
$\frac{1}{2}$	506	109	79·5	87·0	—	—	103	115

Type of aerial, h/λ	Dead-loss resistance: $\frac{1}{4}\lambda$ aerial, $R_D = R_T - R_R$ (practical)	Dead-loss resistance: $\frac{1}{4}\lambda$ aerial, $R_D = R_T - R_R$ (theoretical)	Dead-loss resistance: $\frac{1}{2}\lambda$ aerial, $R_D = R_T - R_R$ (theoretical)	Metre-ampere efficiency, $\frac{h_1^2}{\lambda^2} R_T$, where $h_1 = \frac{E\lambda d}{377\,I}$	Relative watts in aerial to produce given field strength: Practical	Relative watts in aerial to produce given field strength: Theoretical	Relative field strength at same distance with equal power: Practical	Relative field strength at same distance with equal power: Theoretical
	ohms	ohms	ohms		watts	watts	mv./metre	mv./metre
$\frac{1}{4}$	14	6·5	—	$4{\cdot}17\times10^{-4}$	1,000	1,000	1	1
$\frac{1}{2}$	—	—	12	$0{\cdot}66\times10^{-4}$	625	610	1·26	1·28

* A_3 is a constant.

therefore $S = E/E_1 = 0{\cdot}126$.

From Fig. 5, $d_n = 5{\cdot}2 = \frac{\pi x}{2\tau^2\sigma c}$

therefore $\sigma = 10^{-13}$

with $x = 60$ km. and $\lambda = 503$ m.,
$E = 3$ mv./metre and $S = 0{\cdot}6$.

From Fig. 5, $d_n = 1{\cdot}22$, and $\sigma = 10^{-13}$.

Therefore from these curves we find a value of σ of 10^{-13}. The value of σ found,

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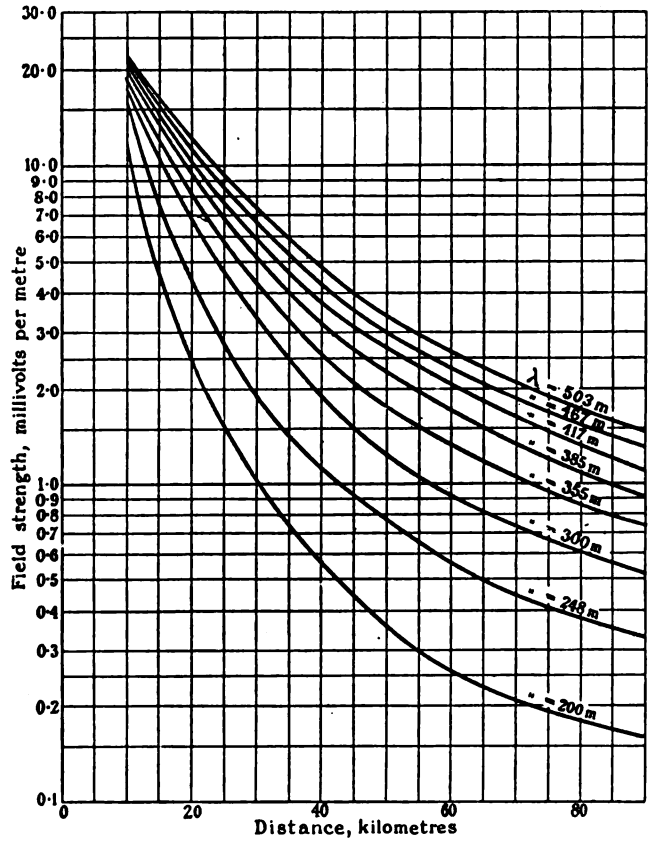

FIG. 6.—*Mean attenuation curve for* $\frac{1}{4}\lambda$ *transmitting aerial with* 10-*ohm dead loss and* 1 *kw. input to aerial.*

as a result of our experiments, lies between the wide limits of from 0·66 to 5×10^{-13} given by other observers, and found by different methods. It is suggested that it is premature to assume that the total value of σ can be accurately subdivided into, for instance, earth loss and vegetation loss. In the generality of cases it would seem unnecessary to assume that there is any loss over and above the earth loss. Exceptions to this are found, however, where the waves traverse large cities or deeply wooded country. More and more "irreproachable" attenuation curves must be taken before this point can be accurately determined, but the labour involved is so considerable that some years must pass before the figures can be expressed with any real certainty. It will, however, be realised that Fig. 5 gives a broadcasting engineer data of the right order needed to forecast the service area of any broadcasting station using wavelengths of between (say) 600 and 200 m.

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Conclusion.

The paper contains too little experimental verification of the theory outlined therein. A conclusion should, however, deal with generalities, and it is obvious from what has gone before that certain incontrovertible principles can be stated. It is time that they were stated before more damage is done by organisations who appear to concentrate on making an undignified scramble for the all too limited facilities rather than thinking how best to use what are, in plain fact, the actual facilities available.

The facts which emerge are these :—

(1) The design of aerials for broadcasting should aim at using the energy to produce the strongest possible horizontal radiation while diminishing upward radiation.

(2) To produce this desirable end, high aerials are a *sine qua non.*

(3) Nothing, however, that is done with special aerial design will prevent a serious limitation of service area, relative to that obtained with the longer waves, when the shorter waves are used.

(4) That, nevertheless, organisations must employ such waves which are more efficiently used by the employment of high aerials.

Responsible technical authorities have in the past been chary of using waves below 300 m. for their broadcasting stations because of their expectation that such stations will have too limited a service area under practical conditions. This may be true in certain cases, but it is to be remembered that limitations are inevitable, and it is better to have a limited service than one which suffers continual interference. The use of shorter waves is perfectly economical in densely populated districts. It is hoped that this final analysis will help engineers to gauge the extent of the usefulness of all waves so that existing facilities may be most efficiently used.

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MARINE DIRECTION FINDERS: TYPES 11G. AND D.F.M.3

With the increased use of Ship Direction Finders has come the need of an efficient and selective, though simple, class of instrument.

The 11G. and D.F.M.3 types of direction finder attempt to meet this demand in a very complete manner, the difference between the two receivers being described below.

The extreme simplicity of the apparatus, combined with high efficiency, make these two models peculiarly adapted to the needs of mercantile vessels which aim at perfection in the design of their direction finding gear.

THE 11G. Direction Finder is designed for use on board all classes of mercantile vessels as a navigational instrument. It is intended to supersede the Type 11F. Direction Finder.

The chief difference between the two types mentioned above lies in the Amplifier. By means of the use of two Marconi S.625 screened grid valves, a short description of the action of which has been given in the November issue of the "Marconi Review," greatly increased amplification has been obtained.

In considering the design of this receiver, it is necessary to bear in mind the fact that accommodation for it will, in many cases, be very limited, that it will be subject to extreme vibration, and that it will occasionally be operated by semi-skilled personnel.

The receiver has consequently been designed

(A) In as compact a form as possible.

(B) As robustly as possible.

(C) As simply as possible.

As regards overall dimensions, the 11G. receiver has been made approximately the same size and general shape as the 11F. The copper screened teak cabinet of the 11F. has been replaced, however, by a sheet brass box, with all the screens, etc., of the same material well bonded to the main case. In this way greatly improved screening has been obtained; the instrument is robust; and the accessibility of the amplifier and tuner has been increased.

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11G.

The apparatus operates on the well-known Marconi-Bellini-Tosi System, and incorporates a radiogoniometer, vertical aerial coupling system, two stages of screened grid high frequency magnification, an anode bend detector, and a resistance capacity coupled amplifier.

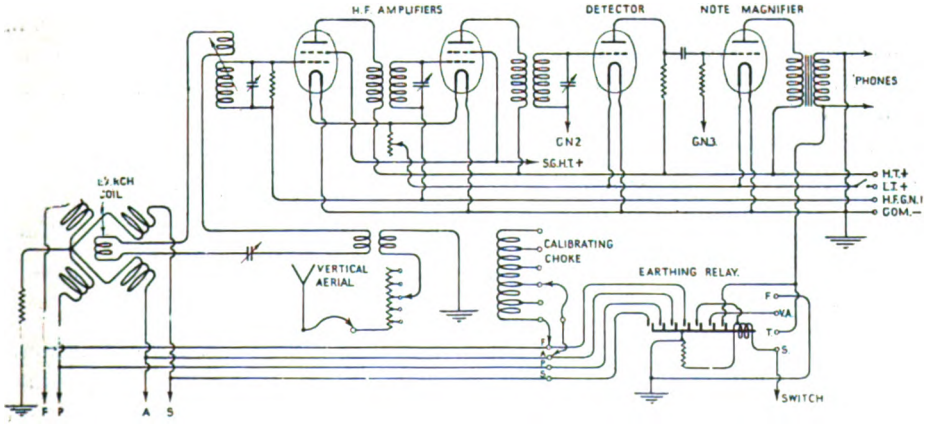

FIG. 1.

The instrument has a waverange of from 450-1,100 metres, and this is covered in a single range.

A simplified diagram of connections to the receiver is shown above (Fig. 1).

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The radiogoniometer consists of two fixed coils of equal impedance, crossing each other at right angles. The four ends of these coils are marked "Port," "Starboard," "Fore," and "Aft," and are connected to the corresponding ends of the aerial loops, and the centre point of each coil is connected to earth through a resistance of 2,000 ohms. These coils are mounted on a hollow cylindrical former, and are well insulated from each other. A rotatable search coil is mounted symmetrically inside the former in such a manner that it can be set at any angle relative to the two field coils, and its direction read off accurately on a scale provided at the front of the receiver.

The vertical aerial itself is connected to the set by means of a plug which can be inserted into a socket on the front of the set. In this way either a figure of eight or cardioid diagram can be obtained.

The phasing resistance for the vertical aerial can be adjusted once for any particular aerial and then left. It will be found that this adjustment suffices to give a sharp minimum as long as this particular aerial is in use.

A calibrating choke is provided in parallel with one of the field coils of the radiogoniometer. This is to provide general compensation for the distortion of bearings by the metal work of the ship. The value of the inductance included in this choke can be altered by attaching a flexible lead to one of numerous tappings on the choke.

The earthing relay is provided for use when the ship's transmitter is working. It consists of a solenoid wound round a soft iron core, which operates contacts connecting aerial leads, telephones, etc., to earth when the magnetising current is cut off. While the relay current is on and the set is working, therefore, all the leads are insulated from earth, but as soon as the switch is broken, the whole aerial system is effectively earthed.

The switch operating the relay is ordinarily situated near the transmitting key.

The amplifier proper consists of two stages of transformer coupled screened grid amplifiers, a detector and note magnifier.

The high frequency transformers are wound in an efficient manner with stranded wire, and have their grid circuits tuned by means of variable condensers. Suitable grid negative is applied to the grids of these valves, and a filament control rheostat is provided.

The detector is of the anode bend type, and the note magnifier is resistance capacity coupled in the usual way.

A telephone transformer is provided for use with low resistance telephones, and has its secondary winding earthed when the set is not in use.

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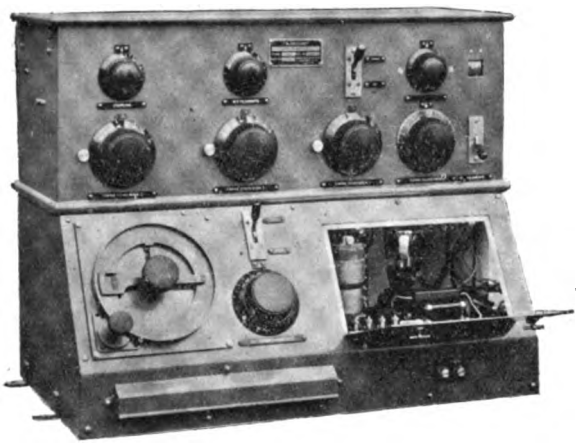

D.F.M.3.

It will be noticed that the set is not designed for use with continuous waves. This is, however, provided for in a modification of the 11G., known as the D.F.M.3.

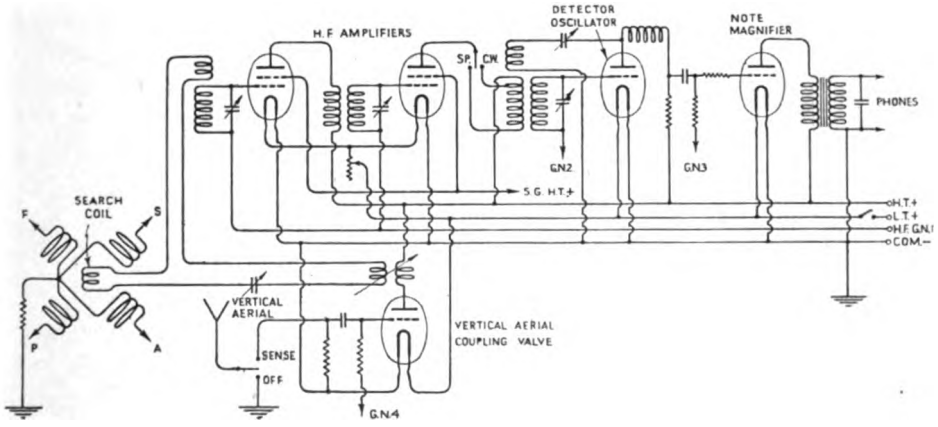

FIG. 2.

The D.F.M.3 has circuit connections very similar to the 11G. (Fig. 2), with the following exceptions :—

(1) Reaction is provided on the detector valve for continuous wave reception and for increasing the sensitivity of spark reception.

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(2) The vertical aerial is coupled to the set by means of a valve. This method has the advantage of allowing the use of quite a small vertical aerial for obtaining "sense" indication by means of a heart-shaped polar diagram of signal strength.

(3) The vertical aerial is connected to the set by means of a switch, and not by a plug as in the case of the 11G.

(4) The D.F.M.3 does not contain an earthing relay. This is intended to be used as an accessory external to the receiver.

(5) A special tapping is provided in the anode coil of the second high frequency valve for the purpose of reducing the coupling during continuous wave reception. The necessary change is made by a switch marked "Spark" and "C.W."

(6) The detector has a coil in its anode circuit coupling back to the previous stage, and a condenser to enable reaction to be controlled.

In both the 11G. and D.F.M.3, S.625's are used in the high frequency stages, a D.E.H.610 for the detector, and a D.E.L.610 for the note magnifier.

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LONG AND SHORT WAVE COMMERCIAL RECEIVERS

Considerable care must be taken with many points in connection with the design of short wave receivers, which may be neglected when dealing with long wave receivers. Experience shows, also, that the shorter the wave the more attention has to be paid to design, if efficiency is to be expected.

There is no doubt that commercial traffic on the short waves is now an accomplished fact, and that, consequently, short wave receiver design is becoming of increasing importance.

In this article an attempt is made to outline, very briefly, two typical receivers made by the Marconi Company.

(*a*) *The R.C.6 for long waves.*
(*b*) *The Beam Receiver, Type R.C.24, for short waves.*

THE commercial radio traffic of the World is at present divided into two main classes :—

(1) Long wave traffic.
(2) Short wave traffic.

Until quite recently it was thought that the longer the wave used, the greater distances could be reached. This was in accordance with all the partially developed and mainly empirical transmission theories of the time, and consequently, when the need for inter-continental wireless services became too great to be overlooked, it was to the long waves that experimenters first turned their attention.

With this end in view, the long wave stations at Ongar and Carnarvon, etc., were erected in the British Isles, and for a time the problem seemed to have been solved in the best possible manner.

With the advent of the Beam system of radio communication, however, all this was changed. Short wave stations, with wavelengths of the order of tens of metres, as against the long waves of tens of thousands of metres, were erected, and it can now be definitely stated that traffic on the short waves is just as reliable and much quicker than on the long waves.

The success of any radio telegraphic system depends on the perfect functioning of three main components These are—

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(1) The transmitter.
(2) The receiver.
(3) The land line intercommunication system.

In this article an attempt will be made to show the essential differences between the receivers used in the two cases—long and short waves—by a brief description of two typical sets. The R.C.6 for long wave working, and the R.C.24 Beam receiver for short wave Beam traffic.

The R.C.6. Long Wave Receiver.

The R.C.6 receiver is intended for inter-continental reception of signals of wavelengths from 6,000 metres to 25,000 metres.

It will be as well, possibly, if a few of the difficulties met with in long wave working are enumerated, and the methods used for overcoming them in such a receiver as the R.C.6 are shown.

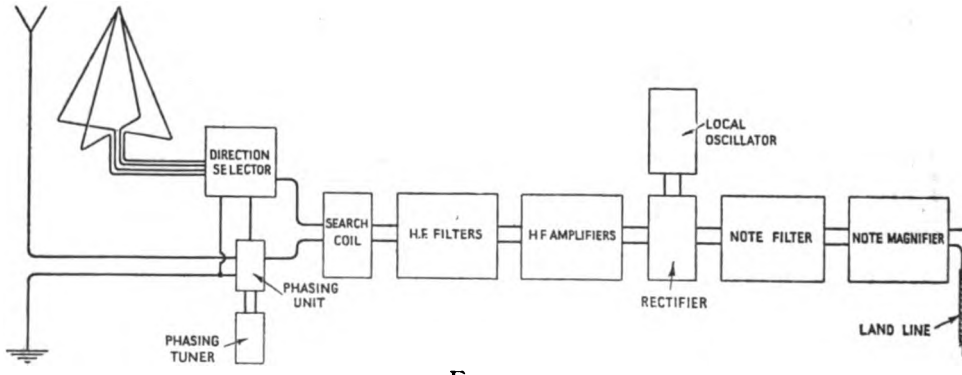

FIG. 1.

Firstly, the receiver used on such work must be reliable. A single breakdown may cause serious congestion of traffic and disorganisation of the service as a whole.

In general, the receiver must be regarded as a purely automatic relay between the transmitter and the Central Telegraph Office, and the attention paid to it, once it has been set up, must be reduced to a minimum.

The land line gear connecting the receiver to the Central Telegraph Office must also be of the simplest construction.

Selectivity is a very important point. The frequency separation of stations is small on the higher wavelengths, and due attention must be paid to this point in the receiver.

Atmospherics are prevalent on these wavelengths, and it is therefore necessary

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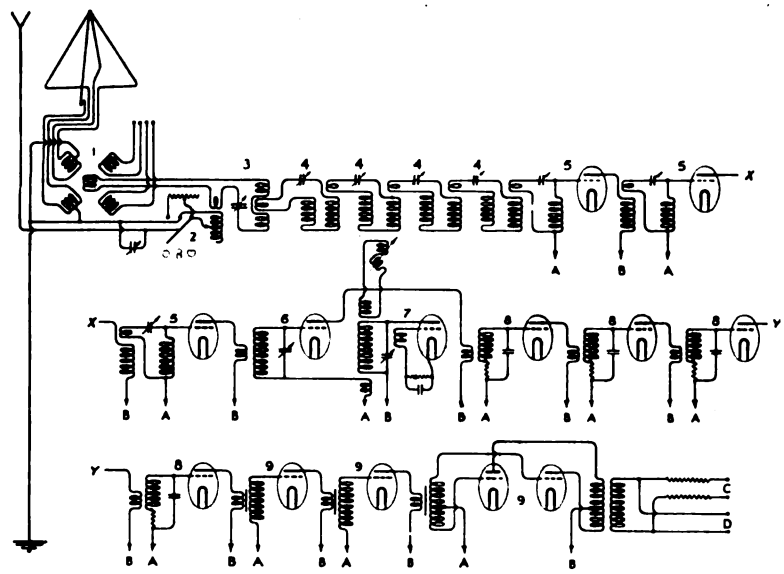

FIG. 2.—*Simplified Diagram of Connections, Type R.C.6c Receiver.*

1. Direction Selector.
2. Phasing Circuit.
3. Tuned Search Coil.
4. H.F. Filters.
5. H.F. Amplifiers.
6. Rectifier.
7. H.F. Local Oscillator.
8. L.F. Filters.
9. Note Magnifiers.

on account of this alone to adopt great precautions in the tuning circuit of long wave receivers.

The R.C.6 receiver obtains great selectivity by the following method :—

(1) Directive reception.
(2) Extensive H.F. filtering.
(3(Extensive Note filtering.

The receiver is designed on the unit principle, and the Beam receiver hereafter to be described is made up in much the same way. Signals are delivered to the land line at any required frequency from 1,000 ∿ to 2,500 ∿.

The following components are contained in the receiver, and will be briefly described below.

(1) Direction selector (Radiogoniometer device).
(2) Phasing unit.
(3) Tuned input circuit.
(4) Four H.F. filters.
(5) Three H.F. amplifiers.

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(6) Rectifier.
(9) Four L.F. filters.
(10) Note magnifier.
(11) Local oscillator.
(12) Control panel.

A schematic diagram of the arrangement of the receiver is shown in the figure (Fig. 1).

The direction selector, input circuits and aerials are arranged on the Bellini-Tosi System, utilising a vertical aerial and two loops. By this means either "all round," "figure of eight" or "cardioid" reception can be obtained by suitable switching. The direction selector is of the double type, to enable several receivers to operate on the same aerial system.

High frequency filtering and amplification is carried out by four low damped tuned filtering circuits, after which are connected three high frequency neutrodyned amplifying units and an anode bend rectifier.

The low frequency amplification consists of four valve-coupled tuned low frequency note filters and a four valve note magnifier, the last two valves operating in "push-pull" to the land lines.

The connections of the receiver are shown in Fig. 2.

All voltages, etc., can be measured and controlled on the control panel from the front of the set, and all H.T. and L.T. supplies to the units are from a series of busbars on the back of the set.

The above description, though brief, will serve to indicate the general design of the set, and to enable it to be compared with the Beam receiver.

The Marconi Mathieu Short Wave Beam Receiver. Type R.C.24.

The short wave receiver used on the Beam system is specially designed to overcome difficulties which only present themselves where dealing with short waves. The chief of these difficulties are fading and alteration of frequency of the signal at the transmitting end. Each of these points is dealt with in a very complete manner in the Beam receiver.

The receiver utilises as its aerial, a system similar to that used at the transmitting end, *i.e.*, an aerial system and a reflector system, each consisting of numerous vertical wires suspended in a line, the length of this line being several wavelengths.

Such an aerial radiates or receives energy efficiently in one direction, this direction being normal to the part in which the aerials are placed.

It is found necessary in such a system to have the currents in all the aerial wires in phase with one another. This condition is obtained by the use of a feeder system, from which the aerials are supplied with energy, or in the case of the

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receiving station, a feeder system is provided to transfer the maximum amount of energy from the aerial to the receiver.

From the feeder system the signal passes through the receiver, the general arrangement of which is shown in Fig. 3, and a wiring diagram in Fig. 4.

The feeder from the aerial system is brought in to a tapped coil on the " R " unit. From thence it passes to the K and A units, where it is heterodyned and modulated at a frequency of about 1,200 ∼ . It is now amplified by a series of push-pull amplifiers in the B and C units, and is heterodyned and detected to land line frequency in the " C " units. After this it is subjected to a further process of push-pull amplification in the I units, and is sent out on to the land line through an impedance changing filter to suit the input of the land line.

As it is intended to superimpose the wireless signals on existing telephone traffic, means have to be provided to introduce the telephone signals and to separate them from the wireless signals. This is done by a " separator " unit. In cases where the telephone signals are desired to be separated from the wireless signals and to be put back on the line, after passing through a sub-station, etc., a " junction " unit is provided. When the aerial line gives place to a cable, or *vice versa*, the impedance of the lines have to be altered to prevent reflection. A " Z transformer " unit can be introduced to achieve this object.

At the recording end of the land line, the signals are passed through another separator unit, and through a filter to a second detector, after which they are again amplified. They then pass through the limiting valve and operate the recorder by means of a marking and spacing valve.

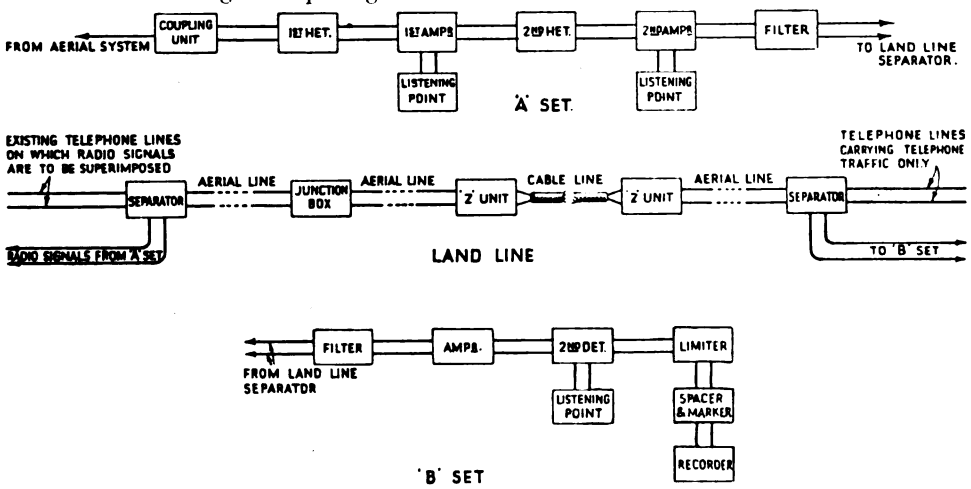

FIG. 3.

The frequency of the incoming Beam signal is from, say, 30,000 kc. to 5,000 kc. ; after the first heterodyne the band of frequencies provided for is from 112·5 to 177·5 kc., and after the second heterodyne, the band is from 21 kc. to 54 kc.

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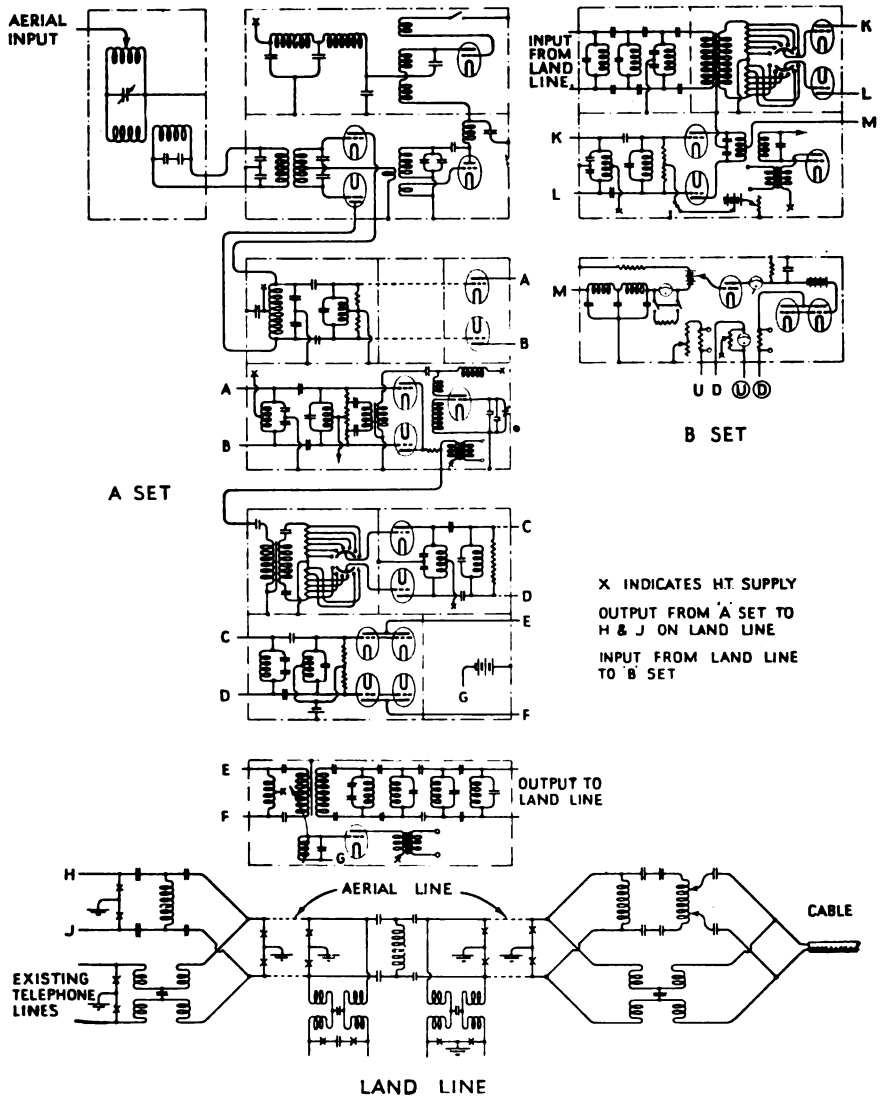

FIG. 4.

The Beam receiver allows for

(A) Variation in the frequency of the oscillation by the provision of "flat-topped" filter amplifiers, which give constant amplification over a small band of frequencies.

(B) Variation in the magnitude of the energy received at the receiving station through fading, by amplifying the signals largely, and then limiting them for recorder purposes.

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NOTES ON BROADCAST TRANSMISSION

In the following article a figure of merit is arrived at which, when applied to a broadcast transmitter, will give some idea as to its capabilities.

A brief statement follows as to the degree of distortion which is permissible in such a transmitter, and the article concludes with a short comparison of the methods of modulation at present available.

The Motala transmitter, which is here illustrated, is a full power modulated set and has a normal rating of 40 kw. to the aerial.

THE design of a broadcast transmitter necessitates a more or less complete knowledge of the conditions under which transmission and reception will be carried out.

Broadcast radio receivers require field strength intensities of from ·02—20 millivolts per metre of effective receiver aerial height for satisfactory operation, depending on the type of receiver, and it is necessary that the transmitter should be designed with such ends in view.

To compare the useful effect upon a receiver of transmitters of various powers, it is necessary to obtain some sort of figure of merit for the transmitter. It is found that the best figure to use is given by the expression

$$P \times M$$

where P is the aerial carrier power

M is coefficient of modulation.

This figure is useful because the received signal strength is proportional to the product of the square root of the carrier power and to the square root of the side band power, *i.e.*, the total effect is proportional to $P \times M$. For example, a 50 kw. transmitter modulated 100 per cent. has a figure of merit of 50, while a 100 kw. transmitter modulated 50 per cent. has an equal figure of merit, so that judged by signal strength alone, these stations are equal. Obviously in the comparison, P should refer to the power actually radiated, so that in practice the stations must be assumed to have the same kind of aerial and the same wavelength.

As to which of the above alternatives should be adopted is a matter involving some complication, since the question of distortion arises in connection with the problem. It can be stated definitely that in the case of a single frequency modulating the transmitter 100 per cent. distortion will be apparent to the ear, but should the full modulation be made up by a combination of various simultaneous frequencies of comparatively small amplitude, the distortion will not be so noticeable.

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There is, however, another factor requiring consideration, and that is the practical value of making provision in the transmitter for a very deep modulation. It must be remembered that the deeper the modulation allowed for, the lower the overall efficiency of the transmitter in the carrier condition, and also that the average modulation level as sent out from the studio is always comparatively low in order to allow of temporary increase in the speech or music. In practice the average level corresponds to between 20 and 30 per cent. modulation of the transmitter. Thus providing for the use of a degree of modulation which can seldom be attained, and even when attained is likely to produce distortion, is certainly extravagant, but there should be some degree of modulation which can be allowed for to give the most effective use under working conditions of a given input power. A reasonable compromise is probably about 70 per cent. or 80 per cent. modulation.

Distortion.

Theoretically all modulation is a distortion of the carrier wave, but in practice if a transmitter is said to give distortionless modulation over a certain range of audio frequencies, it is understood that, within that range, the aerial current will vary in a linear manner with the voltage input to the first modulator.

For instance, if distortionless modulation is guaranteed between 50 and 3,000 cycles up to 80 per cent. modulation, it implies that if an input voltage is applied to the modulator sufficient to increase the carrier aerial current to $\sqrt{1 + \frac{.8^2}{2}} = 1.15$ the unmodulated value, and if this input voltage is maintained constant at all frequencies between 50 and 3,000 cycles, the aerial current will remain constant. The term "distortionless" also implies symmetry of aerial current, that is, an equal rise and fall about the carrier level.

As to the range of frequencies over which distortionless modulation should be arranged for, considerable departure from the ideal of a flat characteristic can be permitted without the ear appreciating the discrepancies. In practice one may say that the ear cannot detect a difference of amplitude unless this exceeds ± 2 T.U., or a difference of 58 per cent. Hence for practical purposes we may regard a characteristic curve which does not vary more than 2 T.U. over a range of frequencies of 50—8,000 cycles as good enough.

Modulation of a broadcast transmitter may be accomplished in several different ways, but one of the following three methods is usually employed :

(1) *Full power modulation.* In this case the voltage on the anodes of the main oscillators is varied by modulators acting on a choke coil or transformer in the anode circuit.

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(2) *Low power modulation.* Here a small oscillator is modulated by a small modulator, and the modulated carrier is amplified up to the required power.

(3) *Grid control.* In the third method the grid current of the main oscillators is varied by means of modulators acting as a variable grid resistance.

It is a little difficult to make useful comparisons between these methods, each having its own advantages and disadvantages.

Whatever method of modulation is used, however, the following points should be borne in mind.

(1) The carrier frequency should be maintained constant.

(2) The frequency of the master oscillator should not be affected by modulation of the transmitter.

(3) The radiated wave should be free from harmonics.

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MARCONI NEWS AND NOTES

THE PHYSICAL SOCIETY EXHIBITION

At the Annual Exhibition of the Physical Society and Optical Society, held at South Kensington on January 8th, 9th, and 10th, the following apparatus was shown, and selected as being typical of the practical side of Wireless Research during the past year.

(1) A direction finder, Type 11G, fitted with an amplifier embodying two stages of screened grid high frequency magnification. This direction finder is intended for use on merchant ships, and is described in the present issue.

(2) A Type R.G.18 receiver, which has been developed for naval and military purposes. The amplifier includes two transformer coupled screened grid high frequency magnifiers, an anode bend detector, and an alternative note magnifier or note filter. A local oscillator is also provided in the instrument. A full description of the receiver will be found in last month's number of THE MARCONI REVIEW.

(3) An auto-alarm receiver and detector, designed for automatically receiving distress signals at sea. The distress signals consist of four-second dashes at one second intervals, which, on their reception by the auto-alarm, ring a bell. This instrument, it is hoped, will do much to eliminate the need of a constant watch being kept by operators on small vessels.

(4) A Type A.D.18 combined transmitter and receiver for aircraft. The transmitter has a waverange of 300 to 1,600 metres, and can be used on either telegraphy or telephony.

(5) A signal strength measuring set designed for use on all wavelengths from 14 to 5,000 metres. Signals from a local oscillator can be attenuated to any extent and made equal to the received signals, either by ear or by a recording device. This instrument is of great use in the determination of transmitter field intensities, etc., and supplies a long felt want.

(6) A component of the Marconi Facsimile apparatus, viz., the tuning fork and thermostat control used in synchronisation of the receiver and transmitter. The thermostat supplied enables the temperature of the fork enclosure to be maintained constant to within 0·1° F. A similar device would, of course, be used on fork controlled transmitters.

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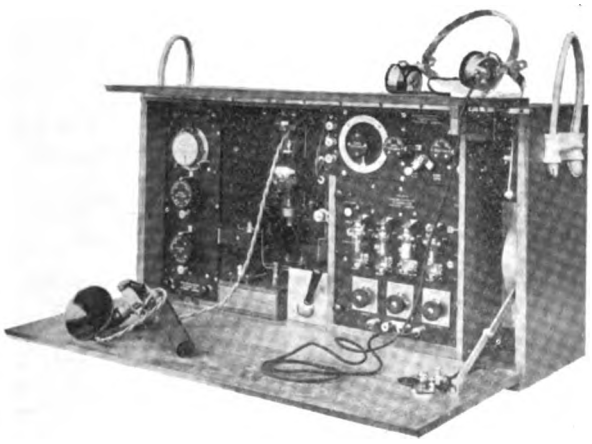
Wireless Apparatus for Harbour Work.



Marconi Portable Transmitter and Receiver. Type YB1.

Marconi wireless telegraph and telephone apparatus has given splendid service to the Authorities of the Port of Basrah in the Persian Gulf, according to a report received from the Basrah Port Directorate.

The wireless sets in use consist of :

Six sets type "YB1" 100 watts.

One set type "U" 500 watts.

The YB1 sets have been in use mainly in connection with the dredging of a new channel through the Bar at the entrance to the Shatt-al-Arab River, some 85 miles distant from Basrah, and they are manned by locally trained Indians under European supervision.

The sets are installed on the dredgers, pilot and control vessels, the Shore Engineering Depot at Fao and Headquarters at Basrah, at distances from each other varying from a few miles up to 85 miles.

The first three sets came into operation in May, 1925, and the remaining three during July, August and December of the same year. They have without exception given entire satisfaction, interruptions of service being very few indeed, and when occurring, have called for adjustments or normal attention to maintenance requirements only. Since their installation it is estimated that they have given an average of over 99 per cent. effective working hours.

Their use has permitted of close and constant supervision of difficult operations, carried out at a distance of 85 miles from Headquarters. Organization in general has been greatly facilitated, and the wireless installation has enabled each particular problem in the course of the work to be given direct personal consideration and be dealt with as it arose without loss of time.

It is difficult to see how the existing standard of efficiency could have been brought about without their assistance.

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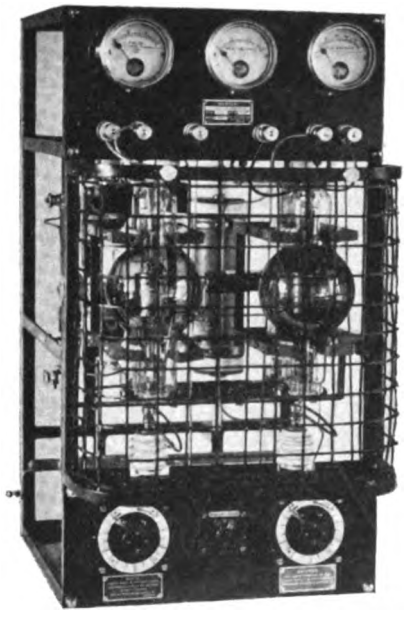
The " U " set is installed on the Light Tender " Nearchus," which vessel's duties include frequent periodic tours of the Persian Gulf as far as Muscat (780 miles) in connection with supervision and maintenance of Lights and Lighthouses.



Marconi Transmitter. Type U.

This set has been in use for a few months only but has given excellent service, and the advantages conferred by its provision are manifest in the conduct of the work.

Goods Telephone Ranges.

In respect to special results achieved the following facts are of interest.

On the occasion of the Dredger " Tigon " proceeding to Bombay for docking :—

Day speech communication was carried out up to 480 miles
,, C.W. ,, ,, ,, 850 ,,
Night speech ,, ,, ,, 750 ,,
,, C.W. ,, ,, ,, 1,400 ,,
with YB1 Apparatus.

That these figures do not represent unusual characteristics is proved by the vessel on her return trip again getting into touch at 1,115 miles after which regular communication was maintained until her arrival at Basrah.

In respect to the " U " type set (500 watts) the Port Directorate is still more or less experimenting, but they have carried out satisfactory tests on 450 metres, up to a distance of 1,200 miles.

It should be rembered that extremes of climate in Iraq are very great, the temperature varying throughout the year from six degrees of frost to 129 degrees in the shade (Fah.), while the variation in humidity is equally extreme.

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No. 5

THE MARCONI REVIEW

February, 1929

CONTENTS

THE MARCONI-WRIGHT FACSIMILE SYSTEM DESCRIPTION OF THE APPARATUS—I - - PAGE 1

A SHORT WAVE NAVAL TRANSMITTER. TYPE T.N.7 - - - - - - - - - „ 9

THE B.B.C. IMPERIAL BROADCAST EXPERIMENTAL SHORT WAVE TRANSMITTER 5SW - „ 14

A DISCUSSION ON H.F. VALVE COUPLED TUNED CIRCUITS - - - - - - „ 18

MARCONI NEWS AND NOTES—

FACSIMILE DEMONSTRATION - - - „ 25

BEAM TRAFFIC - - - - - - „ 32

TRIBUTE TO SENATORE MARCONI - - „ 32

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THE MARCONI REVIEW

No. 5. *February, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

THE MARCONI-WRIGHT FACSIMILE SYSTEM

DESCRIPTION OF THE APPARATUS.—I

The Marconi-Wright system of facsimile transmission and reception is briefly described below under the following sectional headings :—

(1) *Commercial requirements of any facsimile system.*
(2) *Description of Transmitter.*
(3) *Method of synchronisation employed, including,*
(4) *An account of the thermostatically controlled Tuning Fork.*
(5) *The Receiver.*

This article, which will be concluded in the March number, follows the reference which was made to the success of the system in the January issue of THE MARCONI REVIEW, *where a photograph of the apparatus used at the Transmitter end will also be found.*

THE main conditions which must be satisfied by any facsimile telegraph system which is to be operated commercially as distinct from purely laboratory experiments are :—

(1) It is essential that there should be no intermediate process between the acceptance of a message at the transmitting end of the circuit and its handling by the transmitter. By this is meant that there must be no necessity for the reproduction of the message photographically as a transparency, in relief or otherwise.
(2) The transmitting and receiving machines must run continuously. In other words, it must be possible to feed messages into the transmitter and take them off at the receiver without starting and stopping the synchronised rotating parts.
(3) Phase setting at the receiver must be a running adjustment. This can only be achieved if the position of the received message on the receiving surface is at once obvious to the receiving operator.
(4) Ordinary commercial bromide paper must be directly usable in the receiver.
(5) It must be possible to send a message in facsimile, without delay, no

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matter what its shape and size may be (of course, provided that it does not exceed certain maximum dimensions governed by the size of the machines).

These conditions are satisfied by the Marconi system, as will be apparent in the following description of the apparatus. The problem, then, broadly is :

(1) To cause a spot of light to move in a regular fashion over the whole surface of the message, and to modulate a wireless telegraph transmitter so that the depth of modulation is proportional at every instant to the intensity of the light scattered from the message surface.

(2) To cause another spot of light to move in an exactly corresponding manner over the light sensitive surface at the receiver and to vary its intensity with the depth of modulation of the high frequency carrier wave received by the wireless telegraph receiver.

Transmitter.

Fig. 1 is a schematic sectional view of the optical parts of the transmitter.

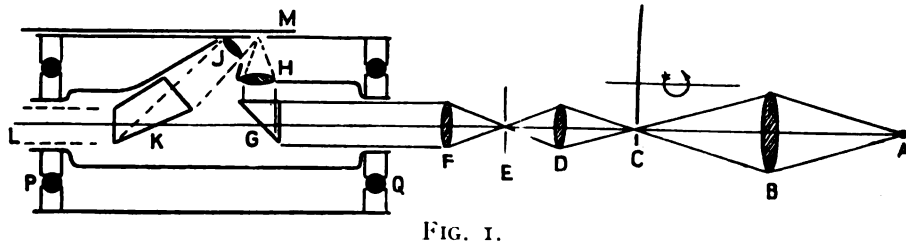

FIG. 1.

A is a light source and consists of a standard pattern concentrated filament heavy current lamp.

The light from this source is collected by a corrected condenser lens B, and a sharp image of the filament is projected on the surface of the chopper disc C. This chopper consists of a steel disc with equally spaced holes near its periphery. The chopper disc runs in a cast iron housing for the sake of quietness and to reduce windage.

The interrupted light beam emerging from the chopper is collected by a second condensing lens D (Fig. 1), and is focussed down to give an intense illumination of the pinhole E. A corrected lens F then collects the light passing the pinhole and converts it into a parallel beam, which travels down the hollow spindle of the synchronous driving motor referred to later.

Reverting again to Fig. 1, the parallel beam from lens F passes down the axis of the optical rotor, falling on the prism G, and thence radially to the lens H. This lens (H), is a fully corrected one and forms a sharp image of the pinhole E on the surface of the message M which is lying on the surface of a cylinder surrounding

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New York T

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USA -

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NEW YORK, SATURDAY, FEBRUARY 2, 1929.

London Music Put on American Radio Chains; Concert Rebroadcast in 'Surprise' Program

Millions of persons in the United States received a radio surprise yesterday afternoon when the music of a symphony concert in Queen's Hall, London, came in over their loudspeakers or head sets.

The London concert was re-broadcast in this country over the National Broadcasting Company's WEAF and WJZ networks, following the broadcasting of the Bok Bird Sanctuary dedication at Mountain Lake, Fla. At the conclusion of the ceremonies in Florida, the American announcer asked all listeners to stand by for "an unusual surprise" in the form of "a program from London, England, over a radio path 3,000 miles long." It was then 4:45 P. M. in New York and 9:45 P. M. in England. Presently the American audience heard the London orchestra playing the last movement of Rachmaninoff's symphony in E minor, which ended at 5:15 P. M. here.

Behind the seemingly simple radio feat lay an intricate scientific arrangement. The music was carried by land wire to the short wave transmitter 5 SW at Chelmsford, thirty miles northeast of London, whence it was broadcast on a 25.53-meter channel. It was picked up at the receiving station of the Radio Corporation of America at Riverhead, L. I., amplified there, transmitted by wire to the distributing panel in the control room of the National Broadcasting Company at 711 Fifth Avenue, then routed to forty radio stations across this country.

The London concert, as it flashed across the ocean, was marred at times by static explosions like the sound of big guns. O. B. Hanson, chief broadcast engineer of the NBC, said this was due to a magnetic storm somewhere on the Atlantic.

Mr. Hanson said the re-broadcast yesterday was "only 50 per cent perfect," adding that in tests conducted over the last three months, foreign programs had been reproduced 90 per cent perfect, but had not been put on the air. He said, however, that the test demonstrated that radio engineers had made big strides in overcoming fading since 1924, when Americans heard Big Ben and the Savoy dance band in London. Yesterday's test marked the first attempt at re-broadcasting a foreign program since 1924.

Officials of the NBC said the English broadcasters were unaware that the program was being re-broadcast in this country. American listeners were critical of the intermissions and the lack of announcements on the part of the English station, both before the music began and after it stopped.

Full scale reproduction of facsimile received across the Atlantic of portion of New York Times *placed direct on Transmitter Drum.*

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the optical rotor. The exact disposition of the message will be made clear later when the traversing mechanism is described. Light is then scattered by the paper on which the message is written or printed and of course, the intensity of the scattered light depends upon the darkness of tone of the spot on which the light falls.

A portion of this light is then collected by the lens J and converted to a parallel beam, which is turned through a suitable angle by the prism and emerges from the rotor axially at L to fall on the active surface of a photo-electric cell.

The whole system of lenses and prisms (G, H, J, K) are mounted in a bronze casting which runs in ball bearings, P and Q.

The optical rotor is mounted in a brass cylinder, having a circumferential slit in the middle in order that the scanning spot may fall on the surface of the message, which is placed face downwards on it.

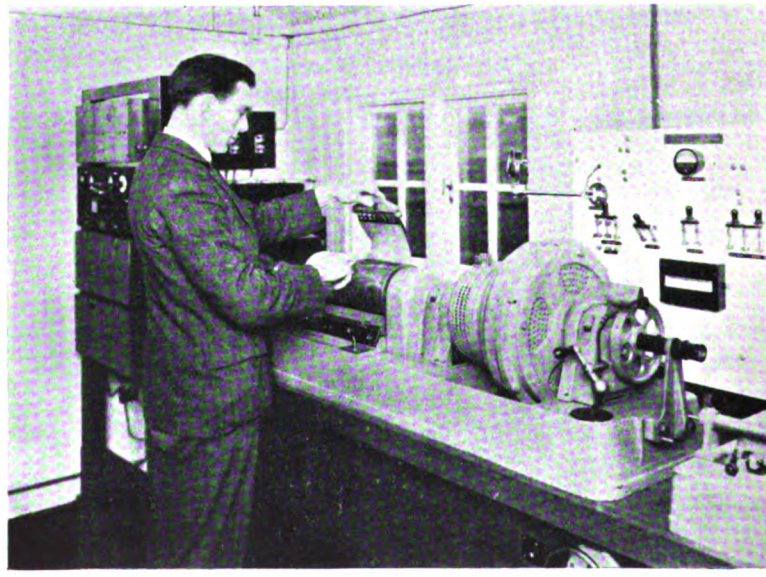

FIG. 2.

The method of inserting the message and of retaining it is shown above (Fig. 2). It will be seen that there is a flexible band supported by a hinged carrier which can be raised from the surface of the cylinder, and when it is so raised the message may be laid, face downwards, on the cylinder. The carrier is then lowered and the flexible band comes down on the back of the message, keeping it in close contact with the curved surface.

Now, assuming that the optical rotor is rotating with uniform velocity, it is

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only necessary to traverse the carrier by means of the usual lead screw, when the flexible band will carry the message with it across the light slit in the cylinder and so the whole surface will be scanned by the spot.

The cast iron saddle is traversed by means of a half nut, which engages with the buttress thread of the lead screw.

Engagement between the lead screw and the main shaft is obtained by a dog clutch hidden by the gear casing. This clutch is operated by the lever, which can be seen projecting up from the front top surface of the bedplate in the photograph. The lever in this picture is in front of the message cylinder and just to the right of the straining weight.

The operations involved in traversing a message therefore are :

(1) With the main shaft carrying the optical rotor running out of engagement with the lead screw (*i.e.*, dog clutch out) the message is placed on the cylinder and is held in position by lowering the flexible band on it.

(2) By means of the lever referred to in the last paragraph the dog clutch is engaged and the message commences to traverse.

(3) At the conclusion of the message the dog clutch is tripped, thereby bringing the carrier to rest.

(4) The flexible band is raised and the message removed.

(5) The carrier is slid along to the left to the starting position in readiness for the next message.

It will be realised that during these operations the optical rotor is revolving continuously, and no phase adjustment or synchronisation is necessary at the commencement of a message.

Driving Machine.

The optical rotor is direct-coupled to the shaft of the driving motor. It consists of a synchronous motor whose speed can be controlled by the frequency of the alternating current supplied to it.

Speed control is secured by supplying the synchronous motor with current from an electrically maintained tuning fork, which is maintained at constant temperature. Variations in speed are secured by either :

(A) Multiplication of the fundamental frequency of the tuning fork, or in the case of a permanent change in the range of speeds :

(B) Substitution of a fork having a different frequency.

In the case of both the transmitter and the receiver the whole driving motor is mounted in trunnions, and can be rotated by the handle seen on the right in the photograph. The purpose of this mounting is to enable phase identity to be secured

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at transmitter and receiver, and for "inching" to correct wandering of phase due to small variations in the frequencies of the controlling tuning forks.

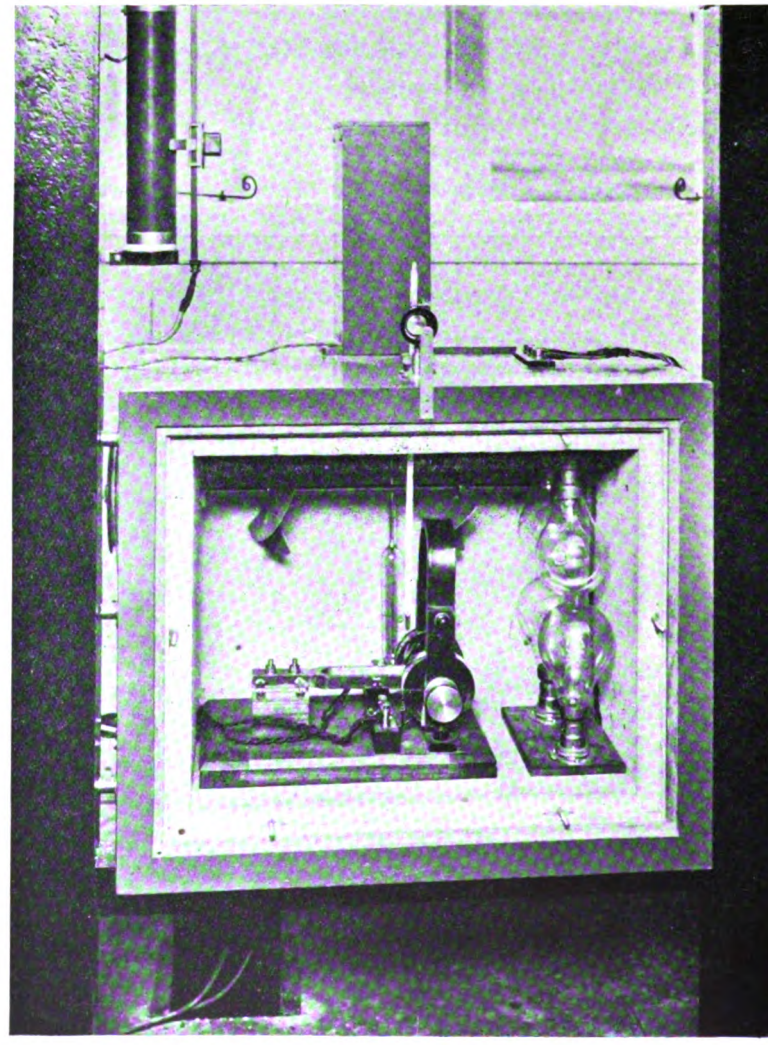

FIG. 3.

On the end of the motor shaft is mounted a stroboscope wheel for setting the motor speed when synchronising the machine with the tuning fork frequency. The toothed periphery of this wheel is illuminated by a small neon tube contained in the shield situated immediately above it. This neon tube is supplied with current from a branch of the tuning fork circuits.

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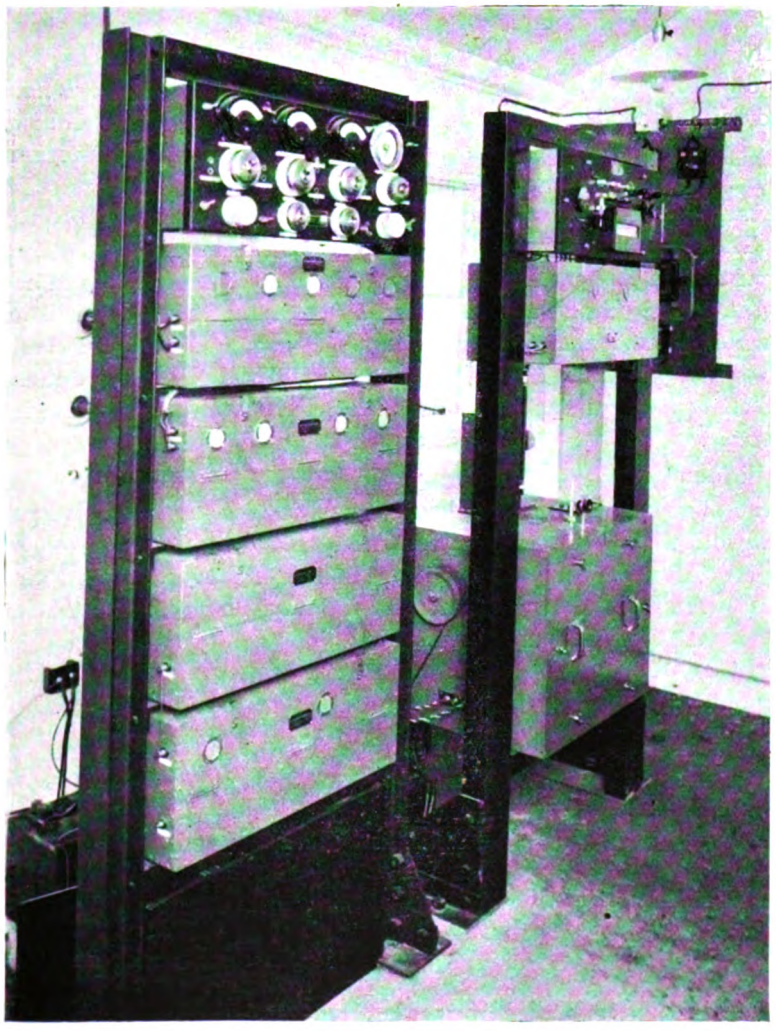

FIG. 4.

Tuning Fork.

The tuning fork is a mild steel one of low damping. It is seen in its mounting in Fig. 3. It is maintained in continuous vibration by reaction in the well-known manner. The whole fork and mounting is placed in the heat insulating box, shown with front removed in photograph, and is maintained at a steady temperature (above that of the room) by means of the toluol regulator seen at the back of the chamber. This regulator closes a contact when the temperature reaches a certain pre-determined value, and through the intermediary of a relay, switches off the heater lamps seen on the right of the chamber. As soon as the temperature falls

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the contact opens and the lamps are switched on again. The air in the chamber is vigorously stirred, by means of two fans at the top back of the box, to avoid a temperature gradient. By this means the temperature of the fork is maintained constant to within about 0·1 degree Fahrenheit. The temperature can be observed by means of the thermometer which projects from the top of the chamber and in front of which is a magnifying glass and peepsight.

Small variations in synchronism are corrected by adjustment of the temperature chamber. There are adjustments made so that this can be done easily by altering the setting of the toluol regulator externally, so that the chamber need not be opened.

The weak alternating current delivered by the tuning fork circuit is amplified for the control of the synchronous motor by the magnifying circuits contained in the rack shown in photographs. Fig. 4 is a view of the front of the rack, and it will be seen that the circuits are contained in four units with the control switchboard mounted above.

Receiving Machine.

The general mechanical, electrical and optical features of the receiving machine are identical with those of the transmitter. The main differences are :—

(1) The pick-up lens for scattered light is omitted from the optical rotor.

(2) A light shutter, operated by the received signal, is substituted for the lamp, chopper and collimator in the transmitter.

The light control device makes use of the Kerr effect in nitrobenzine.

The layout of the optical parts is shown diagrammatically in Fig. 5.

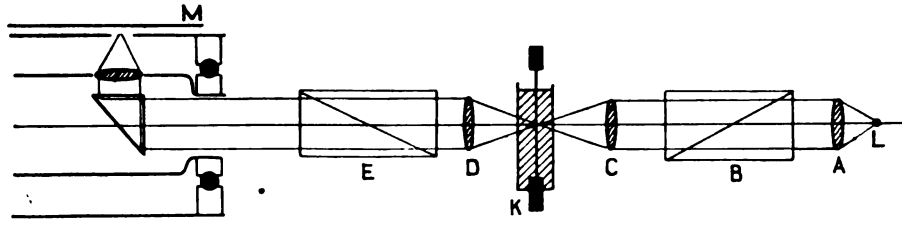

FIG. 5.

A cone of light from the source L is collected by the lens A and emerges as a parallel beam, which is plane polarised by the Nicol prism. After polarisation, the light is focussed by lens C on the gap of the Kerr cell K, and it then falls as a divergent beam on the collimator lens D. This lens again converts the light to a parallel beam, which traverses the second Nicol prism E, and so passes into the receiver optical rotor. This rotor needs no special description. It is precisely the same as that already described in connection with the transmitter, except that the pick-up lens and prism are omitted. The light is finally focussed by the rotor lens as a small spot on the message receiving surface M.

G. M. WRIGHT.

(*To be continued*).

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A SHORT WAVE NAVAL TRANSMITTER

Type T.N.7.

The use of short waves on warships for transmission between ship and shore and for inter-ship communication is becoming more and more general.

The advantages of short wave transmission apply especially to submarine work where the fact that only a short aerial system needs to be employed is of great importance.

The T.N.7 transmitter has been designed, as have other transmitters of the T.N. type, especially for naval use; and their simplicity of control and efficiency make them peculiarly suitable for this purpose.

The transmitter, which is a medium power set with a wide wave range of 16-135 *metres, is contained in a brass frame, and its components are suitably screened.*

THE Type T.N.7 transmitter has been designed as a compact medium power set for use on warships and submarines. It has an input rating of 500 watts to the anodes of the magnifiers and an average input to the anode of the drive of 200 watts. The average aerial power is 250 watts. The nominal waverange of the set is from 16-135 metres, and transmission can be effected either on C.W., I.C.W. or telephony over this waverange.

The complete transmitter consists of three main components :—

(A) The drive ;
(B) The magnifier ;
(C) The modulator ;

the circuits of which are contained in brass frames suitably screened where necessary.

The general design of the H.F. circuits is as follows. A fundamental oscillator, using an M.T.12 valve, drives the magnifier, which consists of two M.T.12 valves in parallel with their associated circuits. The aerial is magnetically coupled to the output circuit of the magnifier. An L.S.5 valve is used as the modulator for telephony, and modulates the magnifier valves by grid leak control. I.C.W. is provided for by a note-oscillator, having three frequencies of oscillation, which works into the microphone transformer of the modulator.

The H.T. supply to the set is by means of a motor generator giving 2,500 volts, and separate voltages of 16 volts and 6 volts are supplied for filament lighting, relay working, etc. Grid negative for the modulator is supplied by dry cells.

To enable a clearer idea of the transmitter to be obtained, we shall describe the components under the following heads :—

(1) Drive and Magnifier circuits.
(2) Aerial System.
(3) Keying and Modulation.

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(1) Drive and Magnifier Circuits.

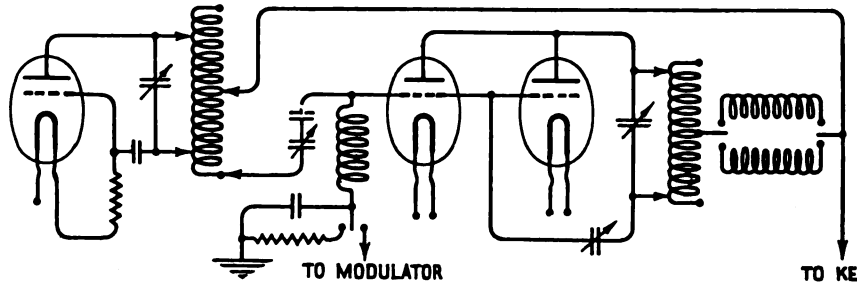

FIG. 1.

A simplified diagram of connections of the drive and magnifier circuits is given above (Fig. 1). The drive will be seen to consist of a simple oscillator with adjustable grid and anode taps to the main inductance. This inductance consists of one coil mounted horizontally, and constructed so that turns can be added one at a time by means of switches. Five values of this inductance are needed to cover the wave-range of the transmitter.

The closed circuit condensers consist of a variable air condenser and a semi-variable air condenser, of which one plate can be switched in at a time. The control of both of these is by handles on the front of the panel.

The drive is directly coupled to the grids of the magnifier valves, a third clip on the main drive inductance being connected to the grids of the magnifier through two condensers, one fixed and the other variable.

The variable condenser provides a fine control of the voltage swing on the grids of the magnifier valves at the shorter wavelengths.

The magnifier closed circuit consists of two coils mounted astatically, H.T. being fed into the centre of the system through one or other of two air core chokes. One choke is used for wavelengths below 60 metres and the other choke for wavelengths above.

Two condensers, similar to those used in the drive circuit, are connected across the ends of the coils. Four valves of inductance are needed to cover the waverange of the set.

A slow motion movement is fitted to the variable condenser, to enable the circuit to be accurately adjusted to the drive circuit.

A hot wire ammeter is provided at the mid point of the astatic inductances for neutralising purposes. This ammeter is shunted when the set is under power and then serves as a magnifier closed circuit current indicator.

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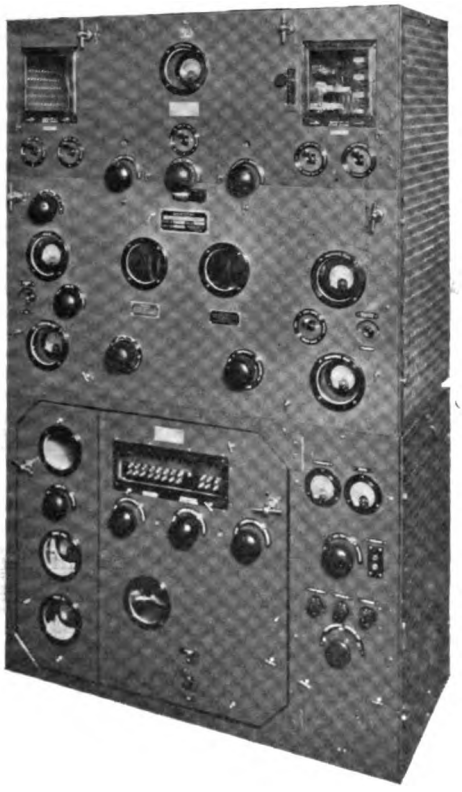

T.N.7. Transmitter completely assembled.

The grid bias of the magnifier valves is set either by a fixed resistance for C.W. or by the modulator valve impedance for I.C.W. or telephony. More will be said of this later.

Aerial Circuit.

The aerial is magnetically coupled to the output circuit of the magnifiers. As has been stated above, the aerial impedance is controlled by means of one of two variable condensers, in conjunction with the coils coupling to the output circuit of the magnifiers. The two variable condensers can be connected either in series between the aerial and the coupling coils or in parallel with the coupling coils. The two coupling coils also can be arranged in series or in parallel by switches.

With this arrangement of aerial control it is possible on any length of aerial to so adjust its impedance for any wavelength that, with the amount of coupling provided by the coupling coils, sufficient energy can be transferred to the aerial to fully load the magnifier valves. The only limitation with regard to the length of the aerial is that it should not be less than one-fifth of the longest wavelength to be used.

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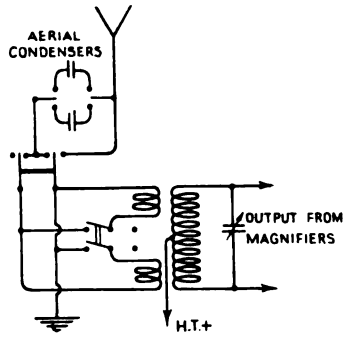

FIG. 2.

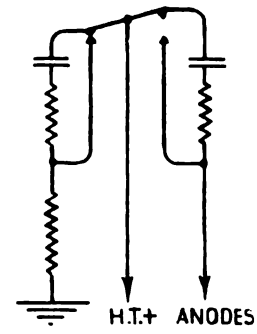

FIG. 3.

This complication of aerial adjustment is rendered necessary by the fact that the set is designed for use on warships, etc., where a variable length of aerial is not generally available.

Keying on C.W.

Keying on C.W. is accomplished by the back load method (Fig. 3). The main H.T. supply to the set is broken by the key on spacing, when the full load of the generator is absorbed by a resistance down to earth.

The key has resistances and condensers across its contacts to eliminate sparking as far as possible.

The method has the advantage that violent fluctuations of anode voltage are avoided, as the load on the generator remains constant.

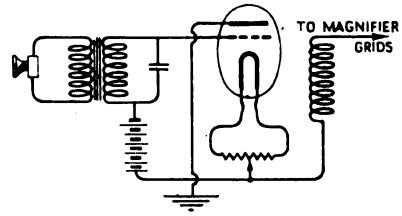

FIG. 4.

Modulation on I.C.W. and Telephony.

As has been stated above, the grid leak method of modulation is used on the T.N.7. This method consists in controlling the input of the magnifier valves by varying the resistance of the magnifier valve grid leak.

The anode impedance of the modulator valve is used as this grid leak resistance, and the impedance is varied by applying the required modulation on to the grid of this valve. The modulator valve is connected with its filament to the grid of the magnifiers and its anode to earth in order that it may pass the grid current of the magnifier valves. The filament battery of the modulator must, of course, be insulated from earth. A diagram of connections of the modulator is given in Fig. 4.

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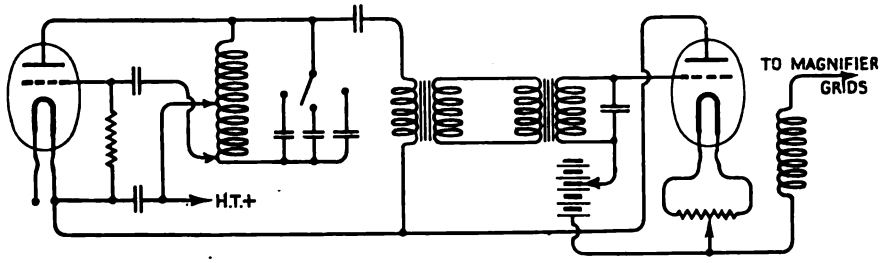
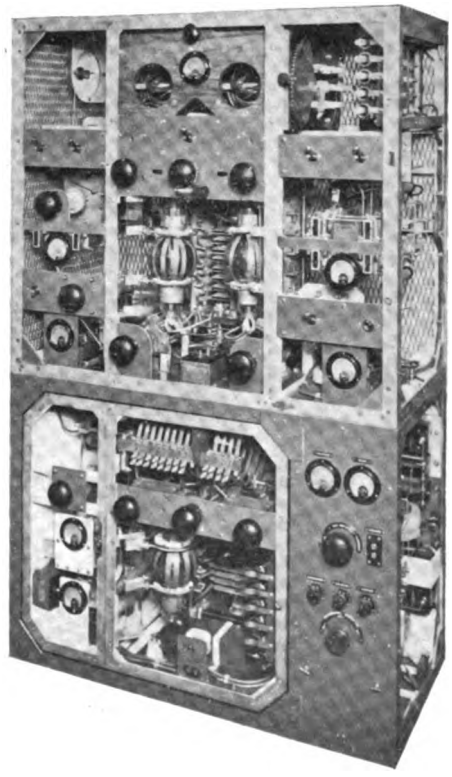


FIG. 5.

The degree of modulation obtained on telephony in this transmitter is of the order of 70 per cent.



T.N.7 Transmitter with front covers removed to show essential circuits.

Note Oscillator for I.C.W.

The note oscillator which is used for I.C.W. signalling is a simple circuit adapted to give three frequencies by the use of three condensers, which can be switched into and out of circuit (Fig. 5).

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THE B.B.C. IMPERIAL BROADCAST EXPERIMENTAL SHORT WAVE TRANSMITTER 5SW

As a result of the success attending the use of short waves for establishing communication between Great Britain and Australia, the public in the British Dominions overseas expressed its keen desire to participate in the National Broadcast movement at home, and asked for special Short Wave programmes to be transmitted for this purpose.

It was recognised by the B.B.C. that provided the obstacles in the way were not too great, it was very desirable that a system of Imperial Broadcast Transmissions which would enable selected programmes from Great Britain to be relayed throughout the British Empire should be introduced.

It was found, however, on examination, that the problem was beset with difficulties, some known, others which were anticipated but could not be defined without trial.

To obtain telephony of good broadcast quality on short waves is more difficult than on long waves; the wavelength which would be most suitable for one Dominion might not be so good for another; the daylight and all-darkness attenuations and the best hours for working to the different Dominions and the fading would be different; also the radical difference in Broadcast hours G.M.T. raised a very important issue.

A compromise service seemed to be indicated, and in order to determine the best arrangement for permanent use, experimental Short Wave plant was installed at Chelmsford, and the now familiar transmissions from 5SW were begun in October, 1927.

AT the Chelmsford Works of the Marconi Company is situated the Short Wave Broadcasting Transmitter working on 24 metres under the call sign of 5SW.

The station is operated on behalf of the British Broadcasting Corporation by the Marconi Company, and the normal duty of the set is to relay the London programme for the benefit of listeners in the British Dominions overseas. The set itself is recognised as being of an experimental character, and no particular trouble has been taken to instal it in a permanent manner. In spite of this, the station has proved very successful during the twelve months it has been in operation, and good reception has been reported from practically every part of the world. Numerous relays of the transmission have been carried out in Australia, South Africa, Canada and the United States.

The station works normally each day, excepting Saturdays and Sundays, between the hours of 12.30 and 1.30 p.m., and from 7 p.m. until midnight. Duplex working

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with 2XAD Schenectady, U.S.A., is also carried out each Monday and Thursday from 5 to 6 p.m.

The apparatus forming the transmitter consists of the high frequency units of a standard Marconi Beam Type Transmitter, together with a modulator unit and the necessary rectifying and smoothing apparatus. A schematic diagram of the installation is given below (Fig. 1).

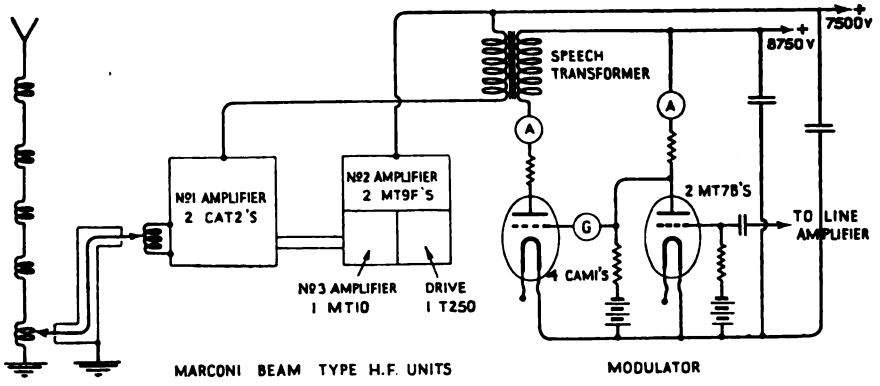

FIG. 1.

The high frequency units, occupying two brass frameworks, comprise a drive, isolator, and intermediate amplifier complete with their oscillatory circuits in one panel, and a main amplifier with oscillatory circuit in the other panel.

The drive uses one valve, Type T.250, and is mounted in a screened case. The anode voltage is given by a 1,000 volt dynamo, and the filament is lit from an accumulator battery. Experience has shown that by carefully maintaining the filament voltage at a fixed value, a very high degree of frequency constancy is obtainable. The input power to this stage is approximately 55 watts.

The isolator is likewise enclosed in a shielding box and consists of one valve, Type M.T.10, with an anode input of 100 watts.

The intermediate amplifier consists of two air-cooled valves, Type M.T.9F, working with an anode input of 500 watts. This stage is arranged to form a completely balanced bridge.

The main amplifier, also arranged in bridge formation, comprises two valves, Type C.A.T.2. These valves are cooled by oil for reasons of efficiency, the oil being pumped through a closed system which passes through a water cooling tank.

The input to this stage is 12 kw. at 7,500 volts in the carrier condition.

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The anode circuit is coupled through an intermediate tuned circuit to a feeder of the enclosed type, that is, a pair of concentric tubes, the outer being earthed along its length and the inner being insulated by porcelain separators. The feeder, approximately 320 feet in length, is connected to a coupling inductance at the base of the aerial.

The aerial is a single wire supported from a triatic about 340 feet high, and is of the Franklin type, incorporating phasing coils, or lumped half-wave inductances, in order that the radiating parts of the aerial may add their fields in phase.

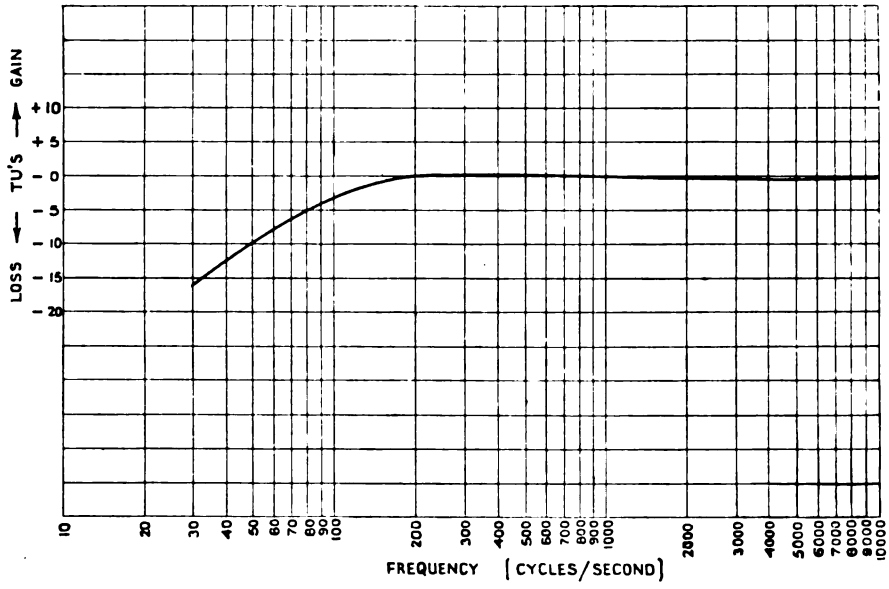

FIG. 2.

The modulating portion of the set consists of a main modulator bank of four C.A.M.1 valves, using water for cooling purposes, and a sub-modulator of two M.T.7B air-cooled valves. The input to the modulator is 14 kw. at 8,750 volts. Modulation is carried out by voltage variation on the anodes of the main amplifier, through the agency of a one to one ratio iron-cored transformer. The full power modulation method is probably the most effective for use on such short wave transmitters, in which there are various difficulties involved in obtaining the required output unless the main amplifier is operating at full efficiency, which, of course, could not occur if the main stage were acting as an amplifier of modulated high frequency in a low-power modulation system.

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This arrangement shows an advantage over the more usual single winding speech choke, as the anode currents of the amplifier and modulator can be connected in opposition in the transformer windings, thus balancing out their magnetising effect on the iron, so that the core need only be of sufficient section to deal with the alternating current component.

Two rectifying and smoothing banks are in use, one supplying the modulator and the other the high frequency stages, although this is not essential.

A degree of modulation of approximately 80 per cent. is obtainable without distortion. The usual land line amplifiers step up the received signals from the London studio to the required level to operate the sub-modulator stage. The connection to London, about 30 miles, is by air line for the greater part of the distance. A frequency characteristic of the set is shown in Fig. 2.

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A DISCUSSION ON H.F. VALVE COUPLED TUNED CIRCUITS

The dèmand for careful design of high frequency amplifying systems, due to the modern conditions under which they work, has, naturally, led to divergent opinions as to the factors on which efficient design should be based.

In this article, the author discusses the tune circuit type of high frequency amplifier from two points of view :—

(1) *Voltage Amplification.*
(2) *Selectivity.*

The effect of the output circuit on these two factors is calculated, and the result of tapping the inductance in this circuit is considered.

Lastly, the article deals with the questions of the limits of " goodness " of coils and of valve amplification factors and impedances.

THE high frequency system of a receiver has to satisfy two conditions, selectivity of a given amount, and amplification, but before discussing the modern valve coupled tuned arrangement, it may be of interest to review the development of general purpose receiver design.

Soon after hard valves came into general use (1918), the number of wireless stations in operation in even the most crowded areas of the world was comparatively few, and in consequence no great degree of selectivity of the tuning circuits was necessary in the design of general purpose receivers. Thus the tendency then was to employ a separate tuning system which would incorporate one or, at the most, two circuits of very ordinary " goodness " and follow this with an H.F. amplifier of the aperiodic type. Such an amplifier, because it was aperiodic, had a high noise level, and hence the total amplification by such means was limited.

With the passage of time, however, because of the large increase in the number of working stations, the conditions under which receivers work have become more exacting and hence receiver design has had to adapt itself to meet new conditions ; whereas in the past, receivers of the general purpose type were of the same broad selectivity, whether they were for C.W. reception or telephony, now they will be designed so as to admit exactly that band of frequencies necessary for the particular type of signal being received. Because a simple tuning system is no longer sufficiently selective for any type of work, and more circuits are wanted, it is found easier to adopt a combined amplifying tuning system, and the aperiodic amplifier has for the moment become a thing of the past. Further, our modern requirements call for greater total amplification, and it will be desirable to say a word as to the limit of

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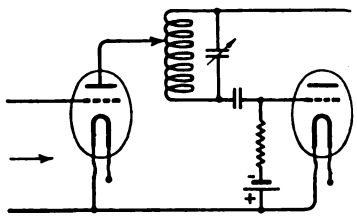
amplification. We may say there are three things which limit the amount of amplification. The first is noise level. One can continue to amplify only so long as the ratio of signal to noise is good. In the older types of amplifiers this was a very important factor which prevented the building of amplifiers having very high amplification. The 55 type, for instance, had an overall amplification of about 800 at its optimum, and at this figure it was very noisy.

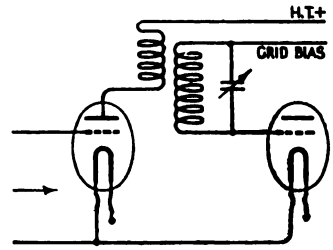
The second factor governing total amplification, if not theoretically, at least economically, is self oscillation. Self oscillation is a function first of feed-back coupling, and secondly of total amplification. Hence the more the total amplification the more the tendency to self oscillate. Thus, as greater amplification is required, greater care must be taken to avoid feed-back coupling, and in modern amplifier design considerable trouble is taken to avoid this by using astatic coils, good screening and careful wiring. The inherent reversible coupling due to valve capacity must also be avoided either by balancing, as with three electrode valves, or by eliminating, as with the screen grid type of valve, the latter method now being universal, where large amplification is desired.

The third factor, governing the amplification per stage rather than total amplification, is the loss of selectivity which may be sustained, but more of this later.



TUNED ANODE

FIG. 1A.



TRANSFORMER COUPLED TUNED GRID

FIG. 1B.

There are two circuit arrangements for the modern type of valve coupled tuned high frequency amplifier, both of which are essentially the same theoretically, the tuned anode which will be analysed, and the transformer coupled tuned grid, one stage of each being shown in Figs. 1a and 1b. In the tuned anode a second winding is saved, but owing to the grid coupling condenser necessary, grid blocking may occur with a high transient voltage such as a strong atmospheric. In both cases we have a valve whose load impedance consists of a tuned circuit, and the aim is to get the biggest voltage step up from grid to grid.

It is desirable to show first the effect of external impedance on the step up obtained with a valve, and Fig. 2 gives the percentage step up of valve volts in terms

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of M for different load impedances Z_e, the latter being in terms of valve impedance. From this curve one can see that the step up increases rapidly from zero to a point where the load equals the valve impedance (where it is ·5M) and from this point onwards the step up increases slowly, only reaching M when Z_e becomes infinity.

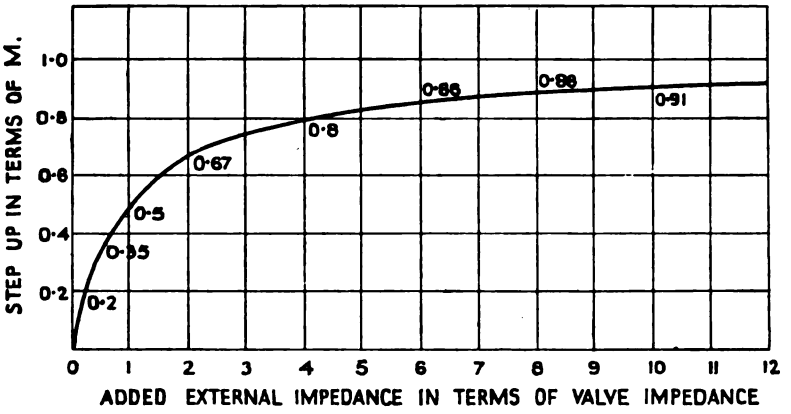

FIG. 2.—*Curve showing the step-up obtained in terms of M for added impedance of different values.*

In the present case the external impedance is a parallel tuned circuit and it is of interest first to consider the ideal. If the circuit has no resistance its effective impedance at resonance is infinity. Thus, if an AC resonant supply is tapped across the whole coil, there is a circulating current set up in LC such that the volts across AB equal the supply volts.

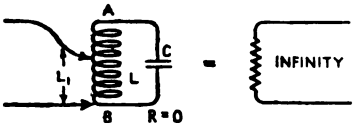

FIG. 3A.

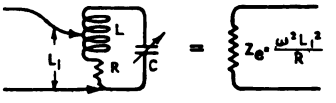

FIG. 3B.

If now the supply is tapped across a part of the coil L_1 say, the effective impedance across L_1 still remains infinity, because the circulating current is boosted up until the back volts across L_1 equal the supply volts. (Fig. 3A.)

Thus considering the perfect tuned circuit as an interstage, if L_1 is included in the plate circuit of the previous valve, because the circuit acts as an infinite impedance load, we could get a change of M volts across L_1 (where M is the voltage factor), and if the grid circuit of the next valve is tapped across the whole coil, we could get a step up of the turns ratio roughly, i.e., $\frac{L}{L_1}$, all assuming zero resistance and no drop in coupling to the grid.

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Note now, how considerably the effect of resistance modifies the action. Resistance in a parallel tuned circuit means the circuit now takes feed current (in proportion to the resistance), and hence such a parallel circuit is no longer an infinite impedance at resonance, but an equivalent finite impedance Z_e (almost resistive) of value $\frac{v}{i}$, where v is the applied A.C. voltage and i the feed current. (Fig. 3B.)

As the feed current is directly proportional to the resistance in the circuit and inversely proportional to the square of L_1, one can find the equivalent resistance Z_e, knowing the constants of the circuit by the formula—

(approximate) $Z_e = \frac{w^2 L_1^2}{R}$ where $w = 2\pi n$ .. .. (1)

L_1 = Inductance between points of tap.
R = Series resistance of LC circuit. We can assume all the resistance is in the coil.

An alternative formula is—

$$Z_e = \frac{L}{CR} \quad .. \quad .. \quad .. \quad .. \quad (2)$$

NOTE.—Both these formulæ only apply at resonance.

From formula (1) it is seen that as one taps down the coil the effective value of Z_e decreases rapidly, and if some actual cases are worked out it will be found that it is not possible to get very high values for Z_e unless the resistance in the circuit is reduced to a very low figure, that is by using very good coils. Thus the effective resistance of a parallel tuned circuit is far from being the infinite impedance one imagines, and the impedance very rapidly comes down as the tap is lowered.

For instance, consider the following quite ordinary circuit working at a frequency of 10^6.

L = 200 mics.
C = ·00013 mfds.
R = 20

The equivalent impedance Z_e at different points of tap will be as follows :—

Tap whole coil = 80,000 ohms.	If R = 20	160,000
,, ¾ ,, = 45,000 ,,		90,000
,, ½ ,, = 20,000 ,,		40,000
,, ¼ ,, = 5,000 ,,		10,000

If R = 10

(The above figures are approximate only.)

Had one used better wire such that the series resistance of the circuit was halved, the figures would be as in column 2, showing a maximum value of 160,000 ohms.

If now we think of such a parallel circuit having resistance, as the load impedance, we can see that as long as we do not fall off the flat part of the curve, we can benefit

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by tapping down, because by tapping down we can get a turns ratio step up, and this is an advantage, provided the primary volts do not fall off in greater proportion. Thus, if we are using a valve whose impedance is really low compared to the Z_e of the parallel circuit, we can get an advantage of voltage step up by tapping down, but if the valve is comparable with Z_e no advantage can be gained.

For instance, consider a valve of impedance 10,000 ohms with an M value of 10 in whose anode is the previous LCR circuit considered. At the whole tap the Z_e of LCR is 80,000 ohms, eight times the valve impedance, and hence the primary volts are ·88 M. Since there is no step up the secondary volts are ·88 M also, assuming no drop in coupling. If we tapped down half way, the Z_e of LCR is 20,000 and hence the primary volts are ·67 M. But there is now a turns step up of roughly 2/1 and hence the secondary volts are 1·34 M. It will be found that the maximum secondary volts are given when Z_e = the resistance of the valve, the curve (Fig. 4) showing this relationship for circuits of different values. These curves are very instructive as they show clearly that unless the $\frac{L}{R}$ of the circuit can be made sufficiently high, so that its impedance is many times the valve impedance, it is not worth while tapping down from this point of view. But there is an equally important point still to discuss, namely, the selectivity of such a system, and how the valve modifies the selectivity at different tappings.

Selectivity.

The selectivity of a parallel resonant circuit is determined by the ratio $\frac{L}{R}$, hence the better the coil the greater its selectivity. If across such a tuned circuit we have a shunt resistance, the latter will damp the circuit in inverse ratio to its resistance and may be considered as throwing back into the circuit an equivalent series resistance of value $\frac{w^2 L_1^2}{Z_e}$, where $w = 2\pi n$, L_1 the inductance between the taps, and Z_e the shunt resistance.

Thus with a shunt resistance infinity no damping is added, but if the shunt resistance approaches that of the equivalent resistance of the tuned circuit considerable effect may be noticed unless that shunt resistance is across only a small portion of the coil.

Now across the tuned circuit we are considering is a valve whose shunt resistance may be comparable to the equivalent shunt resistance of the circuit, and hence the valve will tend to destroy the selectivity of the circuit. The effect will be very marked unless

(1) The valve resistance is very high compared to the equivalent resistance of LC.

(2) The valve is tapped low.

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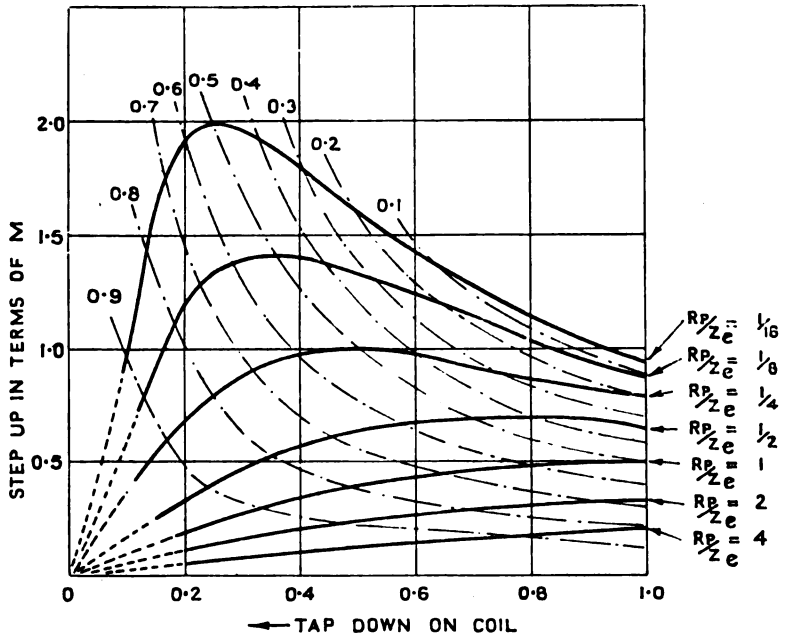
Notice that with a given valve, if we make the coil of the circuit better and do not tap down we hardly gain at all in selectivity.

To show this effect clearly selectivity curves of different factors have been drawn across the impedance curves of Fig. 4, the selectivity of the original LC circuit alone being reckoned as 1. These curves show the addition of damping caused by



a shunt valve of given relative impedance at different tapping points. For instance, if the valve impedance equals the circuit impedance, then the selectivity is halved. This means that if we tap to obtain greatest amplification, *i.e.*, to where Z_t equals the valve impedance, we must sacrifice half our selectivity. At higher taps than this the selectivity is still worse and hence a tap down to below such a point will be better in order not to get too flat tuning. With low impedance valves we are very badly off in this respect, as we require a very low tap to keep up selectivity, and such a tap being critical will not satisfy every frequency. With high impedance valves it is probable we cannot tap up high enough to get anything like the maximum step up, but it may still pay us to tap down as the percentage amplification lost will not matter, and by tapping down we are gaining selectivity.

These curves in conjunction with the previous amplification curves show clearly the effect that altering the ratio of circuit impedance to valve impedance has upon both step up and selectivity.

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As time progresses because design calls for more selectivity and greater amplification, the tendency is to increase the goodness of circuit and raise the M (and R) of the valves used, and it may be realised that when we have made the circuit as " good " as possible, the effect of raising the M and R of the valve is to lose less selectivity, but lose more percentage step up. Because the percentage step up falls off, this does not mean the total step up will be less, but a limit must eventually be reached beyond which increase of M and R cannot give any further increase of amplification per stage. It is dangerous to attempt to state where this limit is, but on ordinary frequencies it may be somewhere about 60. Which means that if we have a valve whose voltage factor is greater than 60, we cannot get a step up of its full M, because we cannot get a circuit good enough. For instance, the standard screen grid valve has an M of 150 at its usual working point, and hence we are working on the bottom of the family of curves shown in Fig 4, from which it can be seen that the maximum percentage step up is very small (of the order of .3), but the selectivity will be very good, and would be better if we tapped down a little.

As the valve impedance is raised we gain less and less percentage step up, and if the valve impedance is high enough it may not be worth while to tap down even from the point of view of selectivity. Thus the circuit goodness, when it is made as perfect as economic and practical conditions will allow, imposes a limit to the design of high M (high R) valves, above which no advantage by voltage step up can be obtained. The fact that valves are being made above this limit (a valve of M=1,200, with correspondingly high R is proposed), does not help us to gain more amplification, but advantage will be gained in keeping up the selectivity, and it is only for such a reason that valves of such an enormous resistance will be of use.

A. W. LADNER.

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MARCONI NEWS AND NOTES

THE MARCONI FACSIMILE TELEGRAPH SYSTEM

DEMONSTRATION OF TRANSATLANTIC OPERATION

MARCONI FACSIMILE
TRANSMISSION TESTS
WAJ LONG ISLAND N.Y.
MY SONG
A SONG is singing in my heart,
It comes there every day.
It used to hum a little bit
And then it went away.
But since I know the story
About the King of Kings
And all the joy his birthday brought
My song just sings and sings.
Subject No 1
Rose Waldo
Editor

A striking example of Marconi facsimile transmission received at Somerton from the United States.

A FURTHER important stage in the development of facsimile transmission over long distances was reached on February 3rd, when a demonstration of Transatlantic transmission of facsimile messages by the Marconi Short Wave Beam Facsimile system was given at the Marconi Beam Receiving Station at Somerton, in Somerset.

This demonstration was given to a number of newspaper correspondents representing the principal English newspapers and technical publications, who were greatly impressed by the excellence of the pictures transmitted from the Beam Station at Rocky Point, Long Island, New York, and received at Somerton.

Not only did the newspapers devote a large amount of space in their news columns to appreciative descriptions and illustrations of the demonstration, but many of them gave leading articles to the subject.

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The *Morning Post*, for instance, said in its leading article that the Marconi Facsimile system has

> " . . . an advantage both in certainty and secrecy : the handwriting is evidence of authenticity, and the message could not be intercepted with the ease that Morse can be picked up. For the system is as great an advance on Morse in the intricacy of its working as the higher mathematics on the tally of a shepherd. Instead of the simple alternation of short-and-long, by which man has been accustomed to telegraph his messages, the varying resistances of a photo-electric cell to light are used to modulate the wireless transmitter and are reproduced in synchronism at the other end. Not a signal merely, but an image is telegraphed. Those varying resistances to light, which, in combination, make what we see of things, are flashed with such rapidity that the picture rolls off the cylinder thousands of miles away as it is exposed to the transmitter. Here, then, is one more development of a new economy of science which is revolutionising, if not annihilating, time and space."

Commendation from Technical Publications.

The *Electrician* and the *Electrical Review*, the two principal English electrical periodicals, also published appreciative editorial comments.

The *Electrician* says :—

> " Our first acquaintance with this system was some two years ago, when the Marconi Company was thinking of distances in yards and obtaining results considerably less definite than those now possible over 3,000 odd miles. The progress made in so short a time is nothing short of remarkable, and is indicative of the enthusiasm which has been brought to bear on the problems involved in the field of electrical research."

The *Electrical Review* writes :—

> " That photo-telegraphy has long outgrown the experimental stage is clearly indicated by the extensive and varied use that is made of the regular commercial services that are available to the public in this country, on the European Continent, and in America ; indeed, last Sunday's demonstration of Marconi's Wireless Telegraph Co., Ltd., suggested that in time facsimile services may largely replace Morse telegraphy on busy circuits, and that the receipt of photo-radiograms, *i.e.*, exact replicas of the senders' hand-written originals, will be the normal procedure.
>
> " Elsewhere in this issue a brief outline of the methods employed will vindicate the claim that they differ from others in use at present : the apparatus is certainly ingeniously contrived and reproduces beautifully clean facsimiles of the originals. Moreover, not only has it been specially

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adapted to operate on short-wave beam radio circuits, thus making it possible to reduce considerably the period of transmission, as compared with long-wave services, but it is also learned with interest that the possibility is contemplated of devising a system of superimposing on one and the same beam radio circuit several telegraph channels, one for facsimile transmission, and one for telephony; in fact, a triplex circuit. Thus is the value of research clearly demonstrated, and the Company is to be congratulated on having obtained results of so high an order of merit."

These independent commendations both from the lay and technical press made after a personal observation of the apparatus at work and of the results achieved are a valuable corroboration of our own claim that we have achieved something far ahead of anything previously developed in facsimile reproduction by wireless.

How the Reporters saw it.

One or two other extracts from newspaper reports may be interesting as giving a glimpse of the demonstration as seen from the outside observer's view point.

The *Daily News*, for instance, wrote :—

From our Special Correspondent.

Somerton (Somerset), Sunday.

"In a 'dark room' at the Marconi 'Beam' Receiving Station here this afternoon I watched a message come through from the other side of the Atlantic in the handwriting of the *Daily News* New York Correspondent.

"All I saw in the dim, red glow was a spot of light running round a cylinder, but three minutes later, when a piece of photographic bromide paper was taken from the cylinder and put into a developing solution the message appeared almost immediately.

"The total time that elapsed between the transmission of the message from Long Island and its appearance in facsimile here was only $3\frac{1}{2}$ minutes.

"The demonstration marks the opening of what promises to be a new era in wireless transmission. Facsimile messages and pictures have been transmitted across the Atlantic by the long-wave system since 1926, but the development of the Beam system demonstrated here to-day is quite new, and opens up many possibilities.

"It is far quicker than the existing long-wave system. The message that took only $3\frac{1}{2}$ minutes to come from New York this afternoon would, I am told, have taken $2\frac{1}{2}$ hours by the long-wave system.

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"This increase in speed, it is claimed, means that facsimile transmission, which up to the present has been of the nature of a luxury, will become the normal thing.

"Eventually, I am assured by Marconi experts, there is no reason why the ordinary suburban telegram sent, say, by a husband delayed at the office, should not be delivered in the handwriting of the sender."

The *Daily Sketch* :—

"In the ruby light of the dark room of the Marconi Beam Wireless Station here this afternoon I watched a beam of light travelling round and round a cylinder of bromide photographic printing paper. Three minutes later I saw the paper removed from the receiving machine and immersed in a bath of developer, and within a few seconds I was able to read the message sent to the *Daily Sketch* by Gertrude Lawrence from New York.

"The message was in the famous actress's own handwriting and the reproduction was perfect. A whole page of a New York newspaper was sent by facsimile transmitter during recent experiments in thirty minutes, and every word on the printed page was readable after the sheet of bromide paper on which it was received had been developed."

North Mail :—

By Candidus.

"At last we have real telegraphy. Ordinary telegraphy does not quite justify its name, for telegraphy means writing from a distance and the telegraph that all of us know sends the message indeed, but not the writing. But the message from Miss Lawrence in New York, which was printed yesterday, was in exact facsimile of her own handwriting.

"I leave the scientific aspects of this new discovery to those who understand them ; I do not. But I am interested in the practical consequence of this new method. It means that if I did not care how much it cost I could get a letter—not a message but a facsimile letter—across the Atlantic in less time than it takes the Post Office to carry it from, say, Hampstead or Wimbledon to the City of London. Does it not follow that the political effects of distance have now been annihilated, such a system which annihilates distance, as this does, has a political value to the British Empire that can hardly be exaggerated. For the purpose of sending and receiving messages, Melbourne is now no further off from London than Edinburgh.

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GERTRUDE LAWRENCE
THE SEVENTY PARK AVENUE
NEW YORK

I am leaving today for Hollywood to make audible moving pictures and I am glad to accept the invitation of the "Daily Sketch" to radio greetings to my dear friends at home in this unique manner. Hope to see you all again soon.

Sincerely
Gertrude Lawrence

Facsimile message from Miss Gertrude Lawrence, the well-known British revue star, sent from New York to England for the Daily Sketch *by the Marconi wireless facsimile system.*

"If there is an elaborate difficulty which needs careful explanation, it can be done promptly by the new wireless system, under which half a page of newspaper can be sent as easily as an ordinary inland telegram."

The *Daily Express* :—

"Strube's Little Man did a lightning sprint across the Atlantic this afternoon. He travelled from Rocky Island, New York, to the new beam Marconi Station here in Somerset—a distance of 2,800 miles—at a speed of 56,000 miles an hour. The Little Man's time for his great Transatlantic flight was only 3 minutes.

"Strube drew the cartoon of the Little Man specially for this historic feat. The cartoon was despatched by liner to America. It was taken to the Marconi transmitting station at Rocky Island and flashed across the

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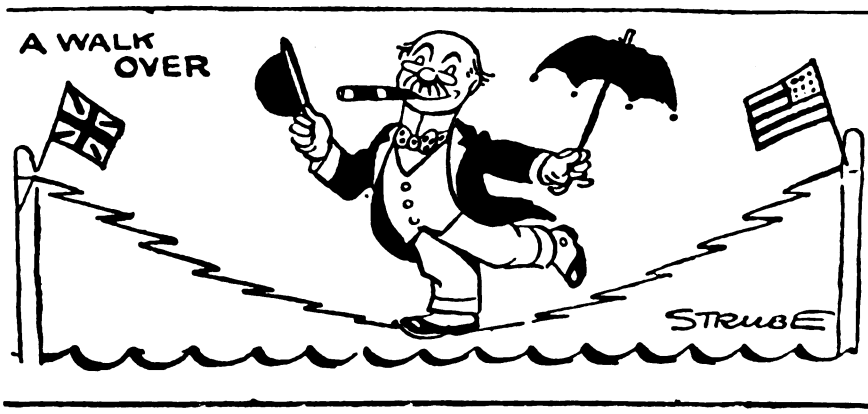

Strube's Little Man, who crossed the Atlantic for the Daily Express *in three minutes during the Marconi facsimile demonstration.*

Atlantic. The transmission was perfect. The wirelessed cartoon was absolutely identical in every respect with the original, a copy of which I held before me for comparison."

The *Daily Herald* :—

"The drawing here reproduced, by our cartoonist, Lance Mattinson, was sent to New York for transmission 6 days in advance. It took just 10 minutes to come back."

History of the Marconi Facsimile Experiments.

Practically ever since the inception of the telegraph, the problem of picture transmission has fascinated electrical engineers. As early as 1842 Alexander Bain invented a highly ingenious system of picture telegraphy, and many others have followed more or less in his footsteps, with widely varying results.

The first telegraphic picture service opened to the public, however, was that, worked on the Ranger system, which has been in commercial operation between Radio House, the Marconi main telegraph office in London, and New York since May, 1926. Some hundreds of news pictures, cartoons, fashion plates, signatures, cheques, and plans have been transmitted commercially across the Atlantic by this system.

The unequalled working speed of the Marconi short-wave Beam telegraph services has now opened the way to further revolutionary achievements in facsimile transmission, and the Marconi Company has during the last three years been developing its system, adapted specially to short wave wireless and to land-line circuits, to give far higher speeds and clearer reproduction than can be obtained by any other method. When such a system is universally adopted it is expected that it will reduce the

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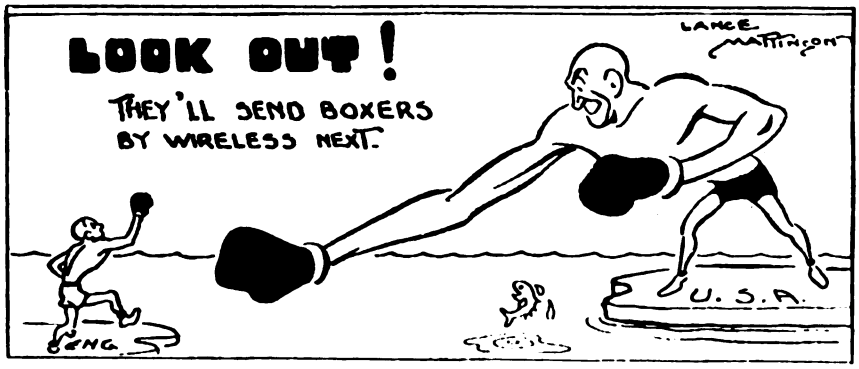

Lance Mattinson's cartoon received at Somerton for the Daily Herald *during the Marconi facsimile demonstration.*

telegraph operating costs, with the result that facsimile telegrams instead of costing more than ordinary telegrams should actually cost less.

In order to produce a system commercially applicable for everyday telegrams, the Marconi engineers deliberately scrapped practically all that had previously been done in the field of picture transmission, and started afresh. The result is that their system differs greatly both mechanically and electrically from any other, and while there are certain difficulties still to be overcome before practical perfection is attained, it is now possible to transmit two images each 8 in. by 10 in. in less than 20 minutes. At the public demonstration messages 10 in. by 4 in. were actually received in $3\frac{1}{2}$ minutes.

These messages have the advantages of unimpeachable accuracy, and—as will be seen from the specimens printed here—the possibility of including not only handwriting but the reproduction of anything that can be written or drawn on paper in the telegrams transmitted—a particularly valuable feature when complicated columns of figures and diagrams are required.

No Stopping.

From the operating point of view, the most important novelty about the Marconi facsimile gear is that it runs continuously. It is not necessary to stop the machinery every time a new picture is put on the transmitter or taken off the receiver. As soon as one message is finished another can be placed on the cylinder and transmission begins at once. This point alone effects a great economy in obviating the running-up of the machinery and synchronising the two ends of the circuit separately for every picture. In addition, no preparation of the message to be transmitted is required; and the reception is perfectly direct and can be checked as it is taking place, enabling faults to be instantly detected and corrected. As the apparatus is ingeniously

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arranged to transmit two pictures at once, in commercial working one channel could be kept busy on "ordinary" telegrams and the other reserved for "urgent" messages, thus providing a valuable commercial advantage.

Suitability for Landlines.

The new Marconi facsimile system is in every way suitable for the transmission of pictures over landlines, the speed with which pictures can be transmitted depending on the quality of the landlines. The same quality which enables landlines to carry the highest musical notes without serious diminution in volume allows the transmission of pictures at maximum speed. The Marconi apparatus is capable of taking full advantage of the quality of the very high grade landlines such as are used for relaying broadcast programmes.

The Marconi Company is indebted to the Radio Corporation of America for the use of the Beam Station at Rocky Point for the transmission of the messages sent during this demonstration.

Christmas Beam Traffic.

The English Beam Stations continue to attract an increasing amount of telegraph traffic, and the figures for the Christmas week, which are now available, constitute a record for any week since the Beam Stations have been open. The total number of words handled during this week was 1,255,201, figures for the various circuits being :—

Australia	382,886	India	368,583
Canada	199,016	S. Africa	304,716
			1,255,201

These figures, which include Christmas Greeting messages, show how efficiently the Beam services are meeting telegraph requirements between Great Britain, its Dominions and India.

Veteran Wireless Operators Pay Tribute to Senatore Marconi.

On February 12th the Association of Veteran Wireless Operators of America held their Fourth Annual Banquet in New York. Their thoughts, of course, turned to the founder of wireless for whom they naturally have a special feeling of regard. During the dinner, therefore, they despatched the following telegram to Senatore Marconi at Rome :—

> "Veteran Wireless Operators of America assembled at Fourth Annual Banquet in the Hotel Astor, New York, send a mighty voice across the ocean and *mare nostrum* to the greatest figure in the world of wireless. This voice carries the warmest sentiments of brotherhood to you our comrade, and through you it reaches the ears of all our comrades in that great society that knows no boundaries. Signed J. F. J. MAHER, *President*."

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No. 6

THE MARCONI REVIEW

March, 1929

CONTENTS

THE MARCONI-WRIGHT FACSIMILE SYSTEM DESCRIPTION OF THE APPARATUS—II - - PAGE 1

THE MARCONI-MATHIEU METHOD OF MULTIPLEX SIGNALLING - - - - - „ 9

THE MARCONI-FRANKLIN PRECISION WAVEMETER - - - - - - - „ 11

THE CALIBRATION OF PRECISION WAVEMETERS BY THE STEP METHOD - - - - „ 15

MARCONI RECEIVERS FOR TIME SIGNALS AND PRESS BULLETINS - - - - - „ 20

MARCONI NEWS AND NOTES—

MULTIPLEX TELEPHONY AND TELEGRAPHY „ 27

WIRELESS FOR RAILWAY STEAMERS - - „ 29

WIRELESS DIRECTION FINDING IN THE ANTARCTIC - - - - - „ 30

T.N.7. TESTS - - - - - - „ 31

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD.

Marconi House, Strand, London, W.C. 2

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THE MARCONI REVIEW

No. 6. *March, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

THE MARCONI-WRIGHT FACSIMILE SYSTEM

DESCRIPTION OF THE APPARATUS—II

In the February issue of THE MARCONI REVIEW, *a general description was given of the Receiver and Transmitter used in connection with the above system of facsimile transmission.*

The vital parts of such a system are :—

(1) *The photo-electric cell or other device used in converting the light energy at the Transmitter end.*

(2) *The light-shutter which converts the electrical energy back to light energy at the Receiver end.*

In the second part of this article, therefore, a short description will be given of the action of the photo-electric cell, and of the light shutter, which, in the Marconi-Wright apparatus, utilises the Kerr effect in nitrobenzine.

Finally, a general description will be given of the electrical circuits used in the apparatus.

The Photo-electric Cell and Transmitter.

THE photo-cell used in the apparatus is of the gas-filled type and depends on the photo-electric effect, or the emission of electrons from the surfaces of some metals when light falls upon them. These electrons can be collected by a suitable positively polarised electrode in the circuit of which will flow a current varying with the degree of light falling on the sensitive surface of the cell.

Now, the response of such a cell is not linear, that is to say, the current does not increase in direct proportion to the frequency of the interrupted light falling on the cell. In any circuit employing such a cell, therefore, some correcting circuit must be employed and adjusted to give a steady voltage across its output circuit for a considerable variation in the frequency of the received light.

The signals from the photo-electric cell are amplified by a cascade amplifier and are passed through filters, etc., to the line (Fig. 1). It is found that a certain

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amount of filtering is necessary in order to cut out all low-frequency components produced by microphonic action of the photo-cell, valves, electrical induction from commutators, etc.

The signals from the line are applied to the input of the power-transmitter, and modulate its carrier wave in the usual way.

Check circuits are provided to enable the voltage of the outgoing signals from the photo-cell amplifier to be read, in order to obtain a relative measure of the signal being put to line. In practice some definite signal strength is decided upon and the signal is maintained at this strength by adjustment of the photo-cell polarising voltage.

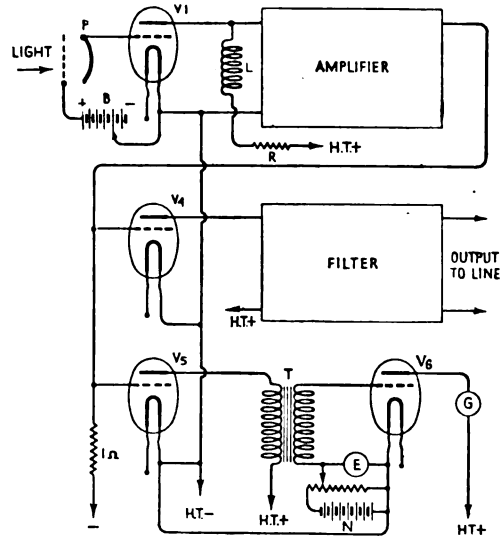

FIG. 6.

The photo-electric cell is contained in a box together with its polarising battery. Potentiometer control of this battery is arranged so that its voltage can be conveniently and quickly varied.

The amplifier, filter system, etc., are housed in metal-shielded units which are supported in iron frames. A control switchboard is provided with all necessary instruments for correct setting of H.T. and L.T. voltages, feeds, etc.

Action of Kerr Cell.

The "light shutter" depends for its action on a physical phenomenon investigated by Kerr in 1875. Kerr found that certain substances exhibit the property

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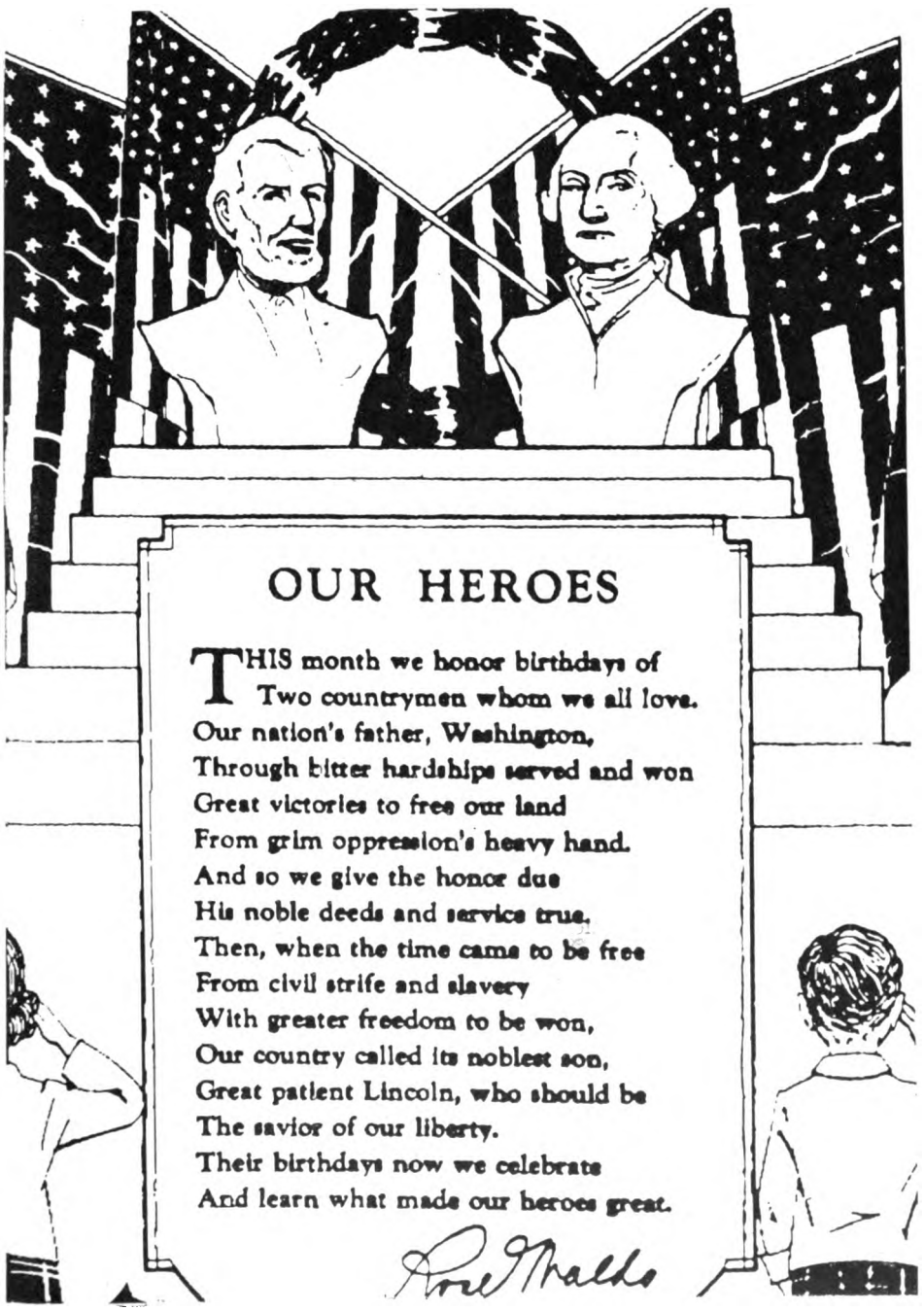
OUR HEROES
THIS month we honor birthdays of
Two countrymen whom we all love.
Our nation's father, Washington,
Through bitter hardships served and won
Great victories to free our land
From grim oppression's heavy hand.
And so we give the honor due
His noble deeds and service true.
Then, when the time came to be free
From civil strife and slavery
With greater freedom to be won,
Our country called its noblest son,
Great patient Lincoln, who should be
The savior of our liberty.
Their birthdays now we celebrate
And learn what made our heroes great.

Full scale reproduction of part of a facsimile received across the Atlantic by the Marconi-Wright system.

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of double refraction when subjected to an electric stress. The manner in which this effect is applied can be seen by a consideration of Fig. 2.

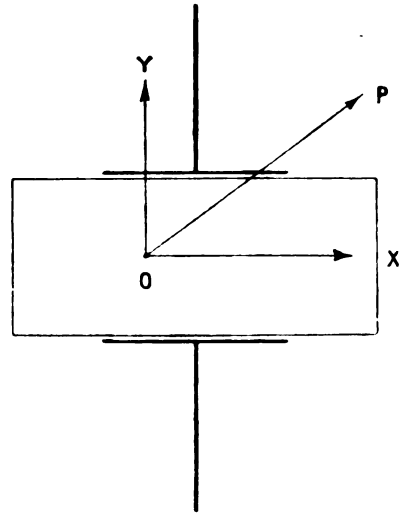

FIG. 7.

In this figure is shown a piece of dielectric interposed between a pair of plates. By applying a voltage to these plates we can stress the dielectric. Now consider a ray of light O passing through the dielectric in a direction perpendicular to the plane of the paper and polarised in the direction OP. This ray can be resolved into two rays polarised in the directions OY and OX. When the transparent dielectric is unstressed these two components pass through a medium with equal velocities, and arrive at its further boundary in phase. The plane of polarisation OP of the initial ray is therefore unchanged, but if an electric force be applied between the pair of plates, then it is found that the component OY, whose direction coincides with that of the lines of force, travels with a different velocity from the component OX at right angles to the direction of the force. The result is that there is a phase difference between the two components on emerging from the dielectric, and consequently the resultant ray is elliptically polarised. This effect is utilised in the receiving machine in the following manner.

A nicol prism polarises a ray of light in the direction OP (*i.e.*, at 45° to the direction of the applied electric force). After traversing the dielectric, which in this case is nitrobenzine, a second nicol prism is arranged so that the light is completely cut off when there is no potential difference applied between the electrodes. If now a sufficiently intense potential difference be applied to the electrodes, then since the emerging light is elliptically polarised, it is no longer completely cut off

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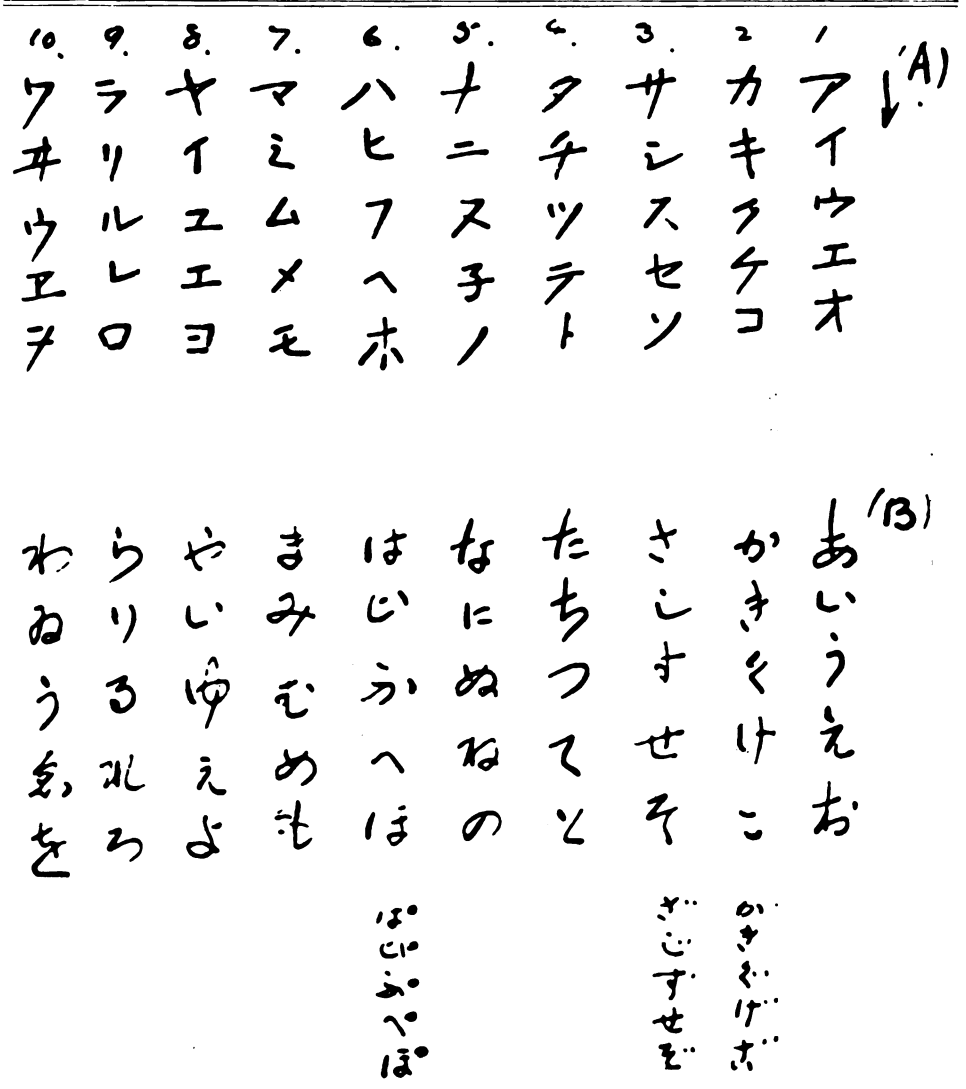

Full scale reproduction of part of a facsimile illustrating the capacity of the system to deal with oriental script. The limiting size of the picture is 9 ins. by 7 ins.

by the second nicol prism, with the result that light can now pass through the complete combination. This device is extremely rapid in action, the lag being quite negligible for the highest frequencies involved in picture reception speeds at present contemplated. It should also be noted that since pure nitrobenzine is a fairly good insulator, the power required to operate the device is very small.

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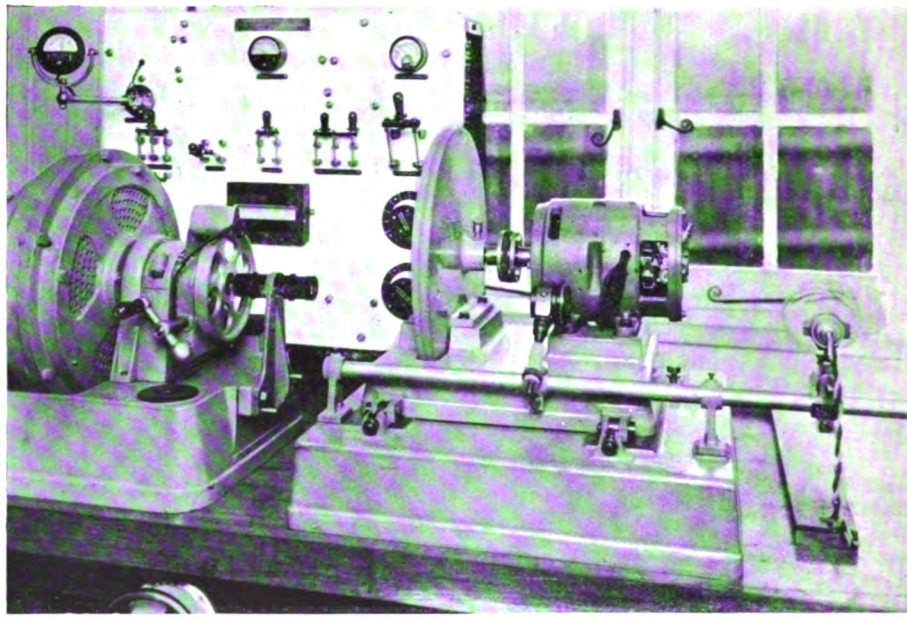
The Kerr cell used simply consists of a glass chamber having parallel sides in which are supported a pair of rounded electrodes. One electrode is carried by a micrometer head, whereby the working gap can be conveniently adjusted to the best length. The Nicol prism is supported in a brass holder by means of cork insets, the whole being finally fixed by running in paraffin wax. The mounting is closed at each end by glass optical flats forming a completely dust-proof case. This protection is necessary inasmuch as the prisms are easily damaged permanently by finger marks on the end surfaces. The general arrangement of the optical parts has already been shown in the first part of this article in the February issue (Fig. 5). The Lamp L is contained in the cylindrical box at the right-hand end of the optical tube. This lamp is supported in such a manner that it can be traversed sideways, or raised and lowered by the milled heads which can be seen on the base of the lamp



Photograph illustrating chopper disc on the right and stroboscopic device for synchronisation mounted on the motor shaft on the left.

box. The lens A is supported inside the optical tube, and its distance from the lamp can be adjusted by means of a knurled ring situated close to the lamp box. A knurled ring also operates the nicol prism carrier and is used for adjusting the relation between the plane of polarisation of the light and the axis of the gap in the Kerr cell. A second knurled ring is provided for adjusting the distance between the lens C and the

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electrodes in the cell. The cell itself is carried in a box, and its position can be set by means of four screws seen, which are afterwards locked. The position of the lenses A and C are so adjusted that a sharp image of the lamp filament of suitable size is formed on the gap in the cell. The lamp is a standard 12v. motor-car head lamp. The light emerging from the cell is collected by the lens D which is capable of adjustment. The position of this lens is set so that a sharp spot is formed on the message surface. The second nicol prism E can also be accurately adjusted with respect to the rest of the system.

In order that the condition of the gap may be readily inspected, a right-angled prism is fitted at the end of the optical tube, and by pulling out a knob, this prism can be interposed in the path of the ray when the gap can be inspected and any necessary adjustment made. A general view of the receiving machine has been shown in Part I of this article, and calls for little comment. It will be observed, however, that the flexible band for traversing the message receiving surface in this case consists of a thin piece of celluloid. A transparent band is used in order that the position of the received message on the bromide paper may be observed during reception. Since the transmitting and receiving rotors are revolving in synchronism,

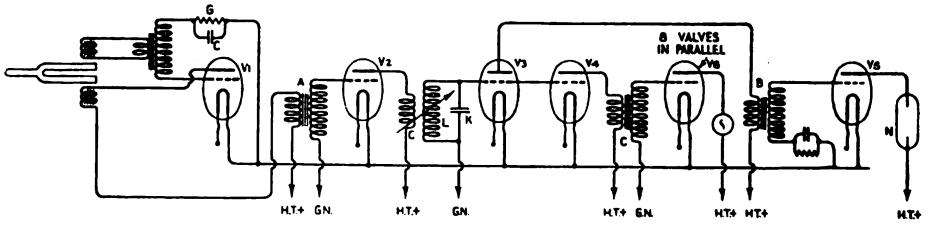

FIG. 8.

the position of the arriving message in the receiving machine can at once be seen by eye, as owing to the persistence of vision the transmitted message appears as a white streak on the receiving surface, and its edges are quite clearly defined. Should

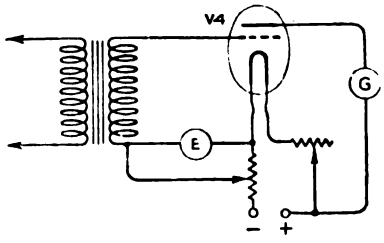

FIG. 9.

this streak not be visible completely from end to end, then it is at once known that the receiving rotor is not in phase with the transmitter, and the necessary adjustment can be made.

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The manner of carrying out this phase adjustment is as follows: A handle situated immediately in front of the driving motor is geared to the carcase of the driving machine; this machine is mounted in trunnions just as was explained in the case of the transmitter, and by means of the handle the whole field magnet system can be rotated, and so the phase position of the rotor adjusted. The synchronism and speed control gear is percisely the same for both transmitter and receiver, and calls for no further comment here. A diagram of the tuning fork circuit is shown in Fig. 3. The tuning fork T is maintained by the valve V_1 in the usual manner. The valve V_1 is coupled to the valve V_2 by means of the transformer A. V_2 is arranged to give an output wave form which is rich in harmonics. In series with the anode of V_2 is a coupling coil inducing an E.M.F. in the resonant circuit LK. This circuit is arranged so that either the fundamental or the second or fourth harmonic of the fork frequency can be selected. In this way the current flowing in LK can be adjusted to be either 300, 600 or 1,200 cycles. This allows of speed adjustment of the optical rotor without changing the frequency of the tuning fork itself.

The alternating potential across LK is applied to the grids of the two valves V_3 and V_4. The output from V_3 is utilised, *via* the transformer B and the valve V_5, to produce a glow discharge in the neon tube N. This tube illuminates the stroboscope wheel on the driving motor spindle, and is used for the operation of sychronising. The output from V_4 is applied through the transformer C to the grids of the bank of eight valves V_6. The anode current to these valves passes through the armature winding of the synchronous motor in the driving machine, thus maintaining it in synchronism with the frequency of the tuning fork or with that of some selected multiple.

A peak voltmeter mounted on the receiver switchboard is provided for indicating when the correct voltage is being applied by the received signal to the electrodes of the Kerr cell (Fig. 4). This indicator is merely a normal "slide-back" voltmeter applied to a few turns on the core of the Kerr cell transformer. The transformer is mounted behind the switchboard.

The switchboard calls for little comment, being similar to that employed for the transmitter.

The general methods of operation are identical with those described in connection with the transmitter. The same mechanical arrangements for clutching and declutching the message carrying band being employed in both cases.

G. M. WRIGHT.

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THE MARCONI-MATHIEU METHOD OF MULTIPLEX SIGNALLING

DEMONSTRATED BETWEEN BEAM STATIONS

ON the 20th May, 1928, the first demonstration of Multiplex working across the Atlantic was given by the Marconi Company between the Beam Stations in Canada and England. As on this occasion a Multiplex receiver was not available for the Canada end, simplex multiplex working only could be shown.

Lately, a second receiver has been installed in Canada, and a series of duplex multiplex tests which were carried out on Friday, March 1st, 1929, before officials

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of the Marconi and Canadian Companies with excellent results, have fully justified all the claims that have been made for the apparatus.

The illustration shows a comprehensive view of the multiplex receiver. A complete description of this will be given shortly in THE MARCONI REVIEW.

The system, as developed at present, permits of the super-position of three modulation channels of communication—two telegraph and one telephone—on one transmitter carrier wave. These three modulations are separated at the receiver end and individually transmitted over their respective landlines to their destinations.

Ingenious methods for the almost complete elimination of fading, the worst enemy of short wave reception, are provided for in the receiver, both in the case of telegraphy and telephony.

These anti-fading devices are based in the well known selective fading properties of the short waves.

The equivalent of sending simultaneously the same messages by two transmitting stations sending on slightly different wavelengths is obtained by modulating the transmitter with frequencies of the order of 7,000 and 9,000 cycles, thus producing side bands respectively 14,000 and 18,000 cycles apart. At the reception these side bands are separated, amplified and the direct current component of the rectification recombines to produce the signals.

It can be shown that the strength of the rectified signal depends on the strength of its carrier. That is to say, if the carrier fades to a very low level or disappears entirely, the side bands, although possibly very strong, will produce no signal after rectification. The new system, therefore, provides for the suppression at the receiving end of the variable carrier, and its reintroduction at the receiver by means of a strong and steady local oscillation.

In the case of the telephone channel, the variable carrier wave is used to work an instrument called the Automatic Gain Control which regulates, by means of relays, an attenuating distortionless network connected between the output of the detector circuit and the low frequency landline repeater.

The photograph shows not only the Multiplex receiver, but also the telephone terminal equipment which permits the extension of the radio 4-wire circuit to any 2-wire subscriber line. These apparatus involve a new system of echo suppressors and measuring apparatus, which will be described later.

The whole receiver, etc., is built up on the unit system, and consists of copper-shielded boxes supported in steel frames. This construction facilitates modification of any circuit to meet special requirements.

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THE MARCONI-FRANKLIN PRECISION WAVEMETER

This wavemeter has been designed to enable beam or short wave transmitting stations to adjust the wavelength of their radiation with great accuracy.

The large number of stations operating on the short wave band 10-60 *metres, necessitates the use of an instrument of considerable precision for wavelength checking.*

The Marconi-Franklin wavemeter allows readings of wavelength to be taken with a maximum error of ± 500 ∿ *between* 15 *and* 60 *metres.*

A PHOTOGRAPH of the wavemeter is shown below. It consists essentially of three condensers—two fixed, and one variable—and a main inductance frame, which, with the condensers, completes the resonant circuit. The three condensers are enclosed in a heavy brass cylindrical case fitted with an ebonite cover, on which are mounted the main inductance frame and the indicating circuit, the latter consisting of a coupling frame, valve and current indicator. The whole instrument is supported on three ebonite legs.

A diagram of connections of the wavemeter is shown in Fig. 1. The main tuning circuit is seen to consist of the inductance, a variable condenser, a fixed condenser, and an extra small condenser which can be switched into and out of circuit by means of a small push-button switch situated on the front of the brass case, and is clearly shown in the photograph.

The indicating circuit consists of a small single turn frame coupled to the main inductance, and connected, one end through a galvanometer to earth or to a source of negative potential, and the other end to the anode of the indicating valve. The grid of the indicating valve (a D.E.3 type receiving valve) is connected to + 40 v. H.T., and the filament of the valve is supplied with low tension current from two dry cells.

Four terminals, connected respectively to the galvanometer, grid, and the two ends of the filament, are provided on the instrument, and can be connected easily to the requisite batteries.

It will be seen that the indicating circuit is very loosely coupled to the tuned circuit, and, consequently, change of valve, H.T., etc., will have an inappreciable effect on the tuned circuit or its calibration.

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The variable condenser of the tuned circuit consists of two fixed sets of plates, and a set of movable vanes which are insulated from the fixed plates. The movable vanes are rotated through a worm drive by a handle which projects from underneath the right-hand side of the base plate.

A pointer, which indicates along a scale on the front base rim of the case, is attached to the spindle of the vanes, so that no backlash can occur between the vanes and the pointer. The pointer is also fitted with a vernier scale to enable readings to be taken with extreme accuracy.

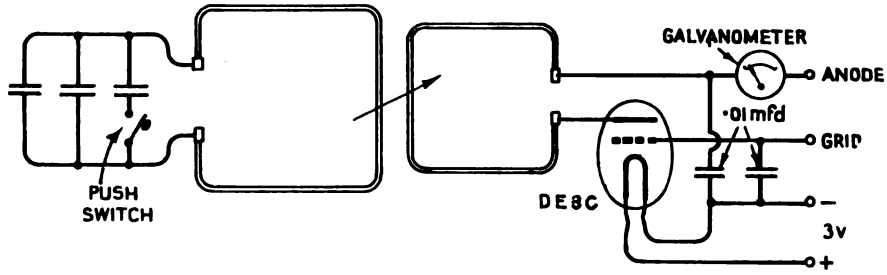

FIG. 1.

In parallel with this variable condenser is the main fixed condenser of such a relatively large capacity that the whole range of the variable condenser only covers ·5 metre to 1 metre change of wavelength, according to the inductance in use.

The interchangeable inductances consist of frames made of ¼-inch copper rod and supported on a glass base. The connections to the condenser are taken from plugs mounted on the ebonite cover of the wavemeter, which fit into brass sockets attached to the under side of the glass base, and to the frame by means of brass screws. This arrangement ensures complete and constant electrical connection, while permitting the relatively quick change of frames.

Operation.

The indicating valve acts as a rectifier. Until the potential of the anode is made positive by the oscillations impressed on the indicating frame from the main frame, no current will flow in the anode circuit of the indicating valve, because the potential of the anode is the same as, or lower than, the filament. When the main circuit comes into resonance, however, the current flowing in the main frame induces a voltage in the indicating frame, the valve proceeds to rectify and current flows in the anode circuit.

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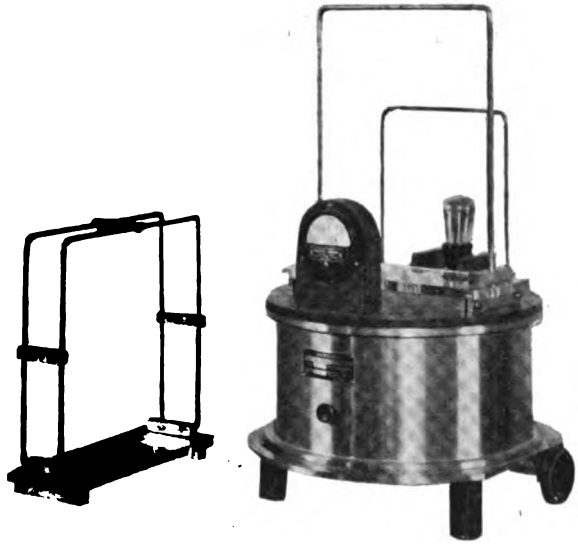
Now if we draw a curve connecting anode current and scale reading of the main variable condenser, we shall obtain such a curve as given in Fig. 2, where A corresponds to the resonance condition. But the curve at A is flat, *i.e.*, the point A is not determinable with great accuracy.



If we now decrease the capacity of our variable condenser till we reach a point B, the curve is very steep, and the point B is determinable with great accuracy. If then we add a small fixed capacity, we shall arrive at some point C on the other

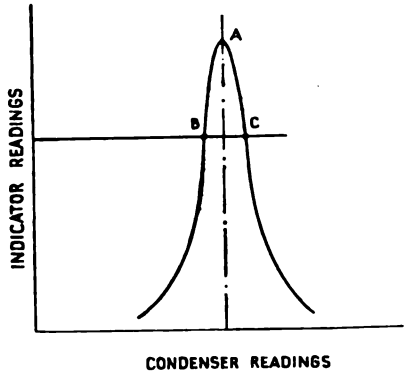


FIG. 2.

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side of the resonance curve. We can arrange for the current at B to be equal to that at C by altering the setting of the main tuning condenser.

The scale reading corresponding to B can then be taken very accurately.

This is the principle of the Franklin wavemeter.

By adjusting the variable condenser until equal readings of the galvanometer are obtained with the key pressed or released, we can obtain a point corresponding to which we can read off the wavelength on the chart supplied.

The range of the wavemeter per frame varies from approximately half a metre at 15 metres to 1 metre at 40 metres. As the scale consists of 100 divisions, and the vernier allows an accuracy of reading of one-tenth of one division, it is clear that at 15 metres an accuracy of measurement can be obtained of ·0005 metre, which corresponds to 700 $\sim$ approximately. Actually the scale can be read to a greater degree of accuracy than this, and an overall error of $\pm$ 500 $\sim$ can be taken as fairly representing the accuracy of the wavemeter.

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THE CALIBRATION OF PRECISION WAVEMETERS BY THE STEP METHOD

In a later article to be published in THE MARCONI REVIEW, *a description will be given of a means of calibrating precision wavemeters using a method based on harmonic selection. In the present article, an alternative method of calibration is given, in which a basic wavelength is accurately measured and other wavelengths obtained from this by stepping this initial wavelength up in small increments.*

The method has been found to give excellent results, and accuracies of the order of 1 *in* 20,000 *can be easily obtained by its use.*

A brief account of the methods usually resorted to in the measurement of short wavelengths by Lecher wires is also given.

IN the description of the Franklin wavemeter given in the previous article, we have mentioned that an accuracy of about 1 in 30,000 can be obtained. This corresponds to approximately 700 $\sim$ at 15 metres. Such accuracy is not of much use if correspondingly accurate methods of calibrating the wavemeter are not available.

In the system of calibration described below, if the value of the initial wavelength be taken as absolute, the limit of experimental error in calibration should be far less than this figure of 700 in 20,000,000.

It will at once be appreciated that the fixing of some basic wavelength presents the greatest difficulty. If we consider, however, a series of transmitters all tuned by wavemeters calibrated from the same standard this basic wavelength becomes of secondary importance when compared with the separation of the transmitter wavelengths one from the other.

This fact has been borne in mind in connection with the calibration of the wavemeter which was primarily designed to fix the frequencies of the series of beam transmitters erected throughout the world.

A preliminary investigation was first carried out to measure, as accurately as possible, some basic wavelength, and to obtain the reading of the standard Franklin wavemeter when tuned to it.

A system of Lecher wires was erected on the closed loop system.

Two parallel wires AB and CD each approximately 15·5 metres long and separated by about 5 cms. were suspended horizontally from insulators about 6 feet above the ground. The ends B and C were joined.

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An oscillator capable of fairly wide frequency variation had its output coil coupled to one end of one of the wires and an indicating circuit was coupled to the wires to determine their resonant frequency. This indicating circuit consisted of a simple turn of wire closely coupled to the Lecher wires and having a crystal detector and galvanometer in series with it (Fig. 1).

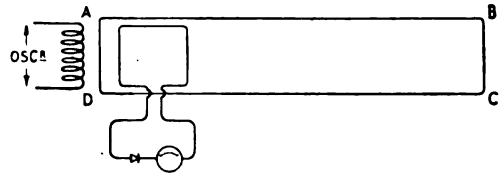

FIG. 1.

An alternative method of indicating the resonant wavelength of the wires would be to couple a powerful oscillator to them, with a milliammeter in the plate circuit of the oscillating valve. As the wavelength of the oscillator is varied a decrease in the reading of this milliammeter would indicate the resonant wavelength. Minor inaccuracies are introduced in both cases owing to the reactive effects of either the indicating circuit or the oscillator on to the wires.

The modes in which such a system of wires can resonate are shown below (Fig. 2) :—

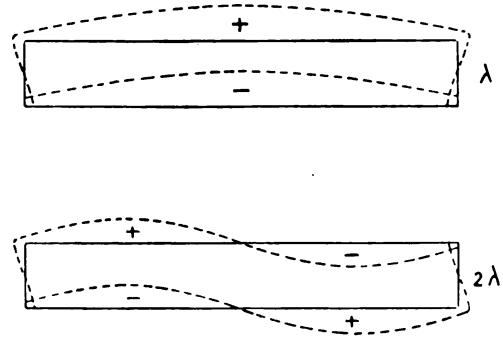

FIG. 2.

In either case it will be obvious that, at resonance, the total length ABCD of the wires will equal

$$\lambda,\ 2\lambda,\ 3\lambda \ . \ . \ . \ . \ .$$

In the case under consideration, the wavelength of the oscillator was known to be of the order of 15 meters, and the length of the wires was measured with great

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accuracy. The wavelength of the oscillator was therefore known accurately and a reading was taken on the Standard Franklin wavemeter to serve as a basis for further calibration.

The greatest difficulty was found in designing some stable oscillating system which, while strong enough to operate the wavemeter, not only at the oscillator's fundamental wavelength, but at, maybe, its 3rd or 4th harmonic, would not be " pulled " to any degree by the reactive effect of the wavemeter on it.

Ultimately the form of oscillator shown below (Fig. 3) was adopted. It consists of a simple oscillator driving two stages of bridge coupled magnifiers to an output frame from which the radiation is received by the wavemeter.

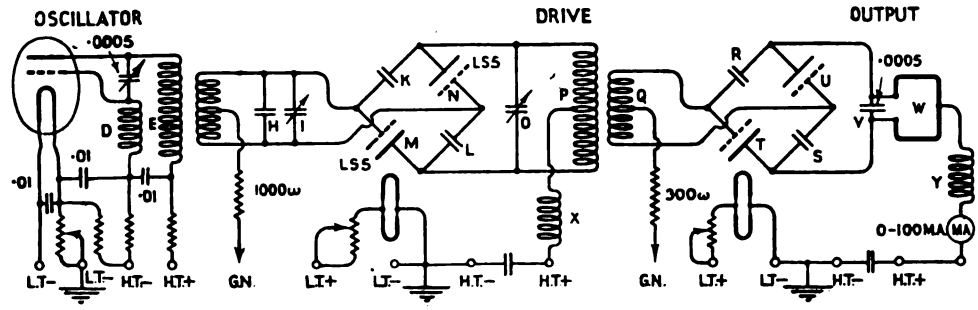

FIG. 3.

Both the input and output circuits of the first bridge and the output of the second bridge are tuned. In this way, both bridges can be tuned to any desired harmonic of the master oscillator.

At the commencement of calibration the master oscillator was set at a wavelength of about 45 metres and the bridges arranged to drive on the 3rd harmonic, a resultant radiation of approximately 15 metres being produced.

The standard wavemeter was set up at a distance of about 3 feet from the output frame of the oscillator and set at the point previously ascertained to be the reading at 15.407 metres. The main oscillator was next tuned accurately to this wavelength.

A subsidiary oscillator, detector and amplifier had been set up adjacent to the main oscillator, and a heterodyne note between the main oscillator and the subsidiary oscillator was obtained. This note was accurately adjusted to a frequency of 1,000 $\sim$ by tuning the subsidiary oscillator. A 1,000 $\sim$ electrically maintained tuning fork was set up, and the 1,000 $\sim$ current introduced into the loudspeaker in which the heterodyne note from the two oscillators was obtained.

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When the subsidiary oscillator was tuned to give a heterodyne note of 1,000 $\sim$ the main oscillator beats could be heard between this note and the fork note. These beats were adjusted to as near a zero frequency as possible, when the subsidiary oscillator was tuned to a frequency 1,000 $\sim$ above the frequency of the master oscillator.

The scheme of connections is shown below. (Fig. 4.)

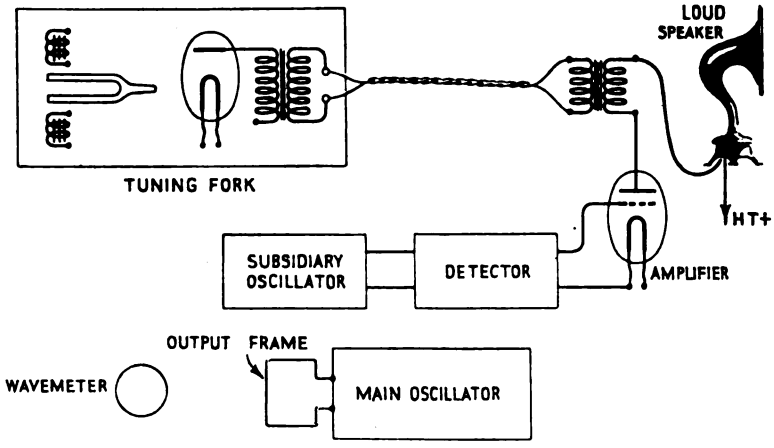

FIG. 4.

Coupling between the detector and the main oscillator was accomplished by means of a short aerial, 4 or 5 feet long, from the detector. Coupling between the subsidiary oscillator and the detector was by means of a coupling coil from the subsidiary oscillator connected to a coupling coil in the detector. The complete arrangement is shown below (Fig. 5).

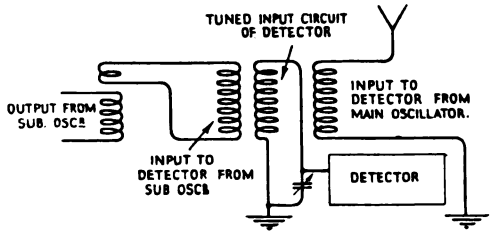
TUNED INPUT CIRCUIT OF DETECTOR
INPUT TO DETECTOR FROM MAIN OSCILLATOR.
OUTPUT FROM SUB. OSC.
INPUT TO DETECTOR FROM SUB OSC.
DETECTOR

FIG. 5.

So far, then, we have the standard wavemeter set at the predetermined reading for 15·407 metres, the master oscillator radiating a wave of exactly 46·221 metres, and also a third harmonic of 15·407 metres which is being received by the wavemeter, and the subsidiary oscillator tuned to exactly 1,000 $\sim$ above this wavelength.

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If the wavelength of the Master oscillator be now raised, the heterodyne note will pass from 1,000 $\sim$ through zero beat to 1,000 $\sim$ again, where it will beat again with the 1,000 $\sim$ note from the tuning fork.

The wavelength of the master oscillator is now 46·221 metres + 2,000 $\sim$. Hence the wavelength of the radiation which is received on the wavemeter frame is 15·407 metres + 3 × 2,000 $\sim$ or 15·407 metres + 6,000 $\sim$ since we are operating on the third harmonic. The wavemeter can be tuned to this new wave and a scale reading corresponding to 15·407 metres + 6,000 $\sim$ obtained.

In this way the main and subsidiary oscillators can be raised alternatively in steps of 6,000 $\sim$ and corresponding readings obtained on the wavemeter.

Steps of 6,000 $\sim$ will, of course, only be obtained when using a 1,000 $\sim$ note tuning fork and operating on the third harmonic. In general the step will be $2nf$ where n is the harmonic number and f is the frequency of the tuning fork.

The number of readings taken per frame of the wavemeter will vary, of course, with the wavelengths covered by the frame. Actually the number varies from above 120 to 70.

The accuracy of the method is very high. Assuming a maximum accidental personal error in obtaining beat silence of 10 cycles, which is quite as much as occurs in practice the total error per frame varies from 700 $\sim$ to 1,200 $\sim$ which will correspond to an error of approximately the same order of magnitude as that occurring in the wavemeter.

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MARCONI RECEIVERS FOR TIME SIGNALS AND PRESS BULLETINS

I.—R.G.12

Wireless time signals which are now transmitted by many stations throughout the world have provided surveying and exploring parties with an accurate method of determining longitude; and the development by the Marconi Company of their selective and sensitive receiving apparatus has considerably widened the field over which these time signals can be received.

In fact, with these receivers—known as Types R.P. and R.G.—it is now possible to receive time signals in almost any part of the world.

These receivers are also suitable for the reception of broadcast news bulletins and for official transmissions from such stations as Rugby, Nauen, Marion and the Eiffel Tower.

Most of these official news bulletins are transmitted by high-power long wave stations for the reception of which the Marconi Press Receiver Type R.G.12 working on a wavelength of between 10,000 and 25,000 metres is particularly suitable.

The selectivity of this receiver is of such a high order that two stations of great strength and lying in the same direction can be separated if their frequencies differ from each other by no more than 120 cycles per second.

The success of this receiver has been phenomenal and orders have been received for it from official and newspaper organisations in all parts of the world.

THE R.G.12 Receiver is primarily designed for press work, and combines high selectivity with great range. Reception of long distance signals is obtained by two stages of high frequency magnification, followed by ample audio frequency magnification, and selectivity is ensured.

(A) by the directional properties that the aerial system possesses;

(B) by the tuning of the high frequency stages, the frame aerial circuit, etc.;

(C) by the system of note-filtering employed.

Two aerials are used on the receiver; one, a 35-foot vertical aerial, which is attached to the grid of the first or sense valve, serves to give a circle diagram; the other, a rotatable tuned frame, gives a figure of eight diagram. When used together, a cardioid polar diagram is produced, and the receiver can be used to determine both the direction and sense of any station.

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A fair degree of high frequency selectivity is obtained by the use of a number of tuned circuits in cascade, and a high degree of overall selectivity by the addition of two stages of audio frequency tuned circuits.

The simplified diagram of connections of the receiver is given below (Fig. 1), and the following is a brief description of the individual components.

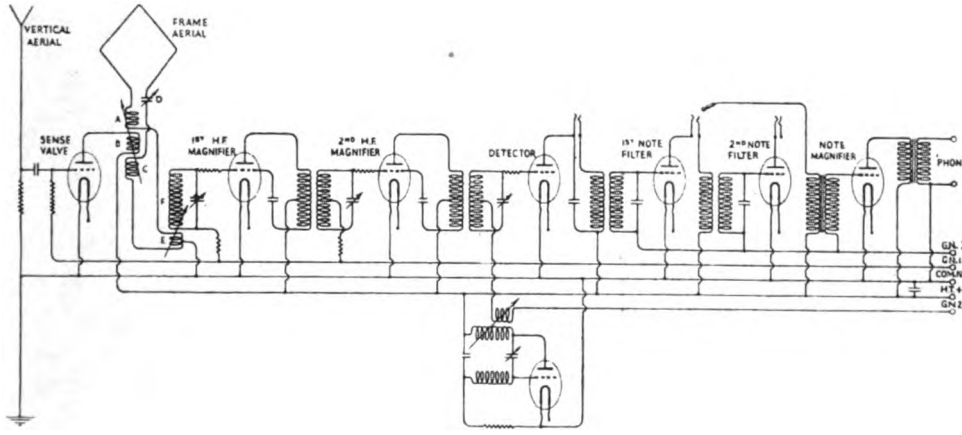

FIG. 1.

The frame aerial, which consists of a square frame of from 10 turns to 32 turns (depending on the waverange of the set), is tuned with a variable condenser in series with it to the wavelength of the desired signal. The vertical aerial is coupled to the sense valve as is shown later, and the amplified signal from this valve is passed through a coil which is coupled to the frame aerial coupling coil in which the frame aerial current is circulating. The resultant signal is applied to the grid of the first high frequency valve. After passing through two stages of high frequency amplification the signal is heterodyned to an audio frequency by means of a local oscillator incorporated in the set, and is rectified by means of an anode bend rectifier.

It is then passed through two stages of transformer coupled audio frequency amplifiers, the grid windings of the transformers being tuned to a frequency of 1,200 v. After passing through these filters the rectified signal is amplified further by an untuned transformer-coupled note magnifier, and is received on low resistance telephones through a telephone transformer.

As will be seen from the diagram of connections for the receiver, the signals from the vertical aerial, after having been amplified by the sense valve, are introduced into the frame aerial circuit by means of one coil B in the anode circuit of the sense valve coupling into the coils A and C in the frame aerial circuit.

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The coupling coil E, which serves to transfer the resultant signal from the frame aerial circuit to the first high frequency valve, has its centre point connected to earth. This is done to ensure complete symmetry of current distribution in the coil and to eliminate " vertical."

A simplified diagram of the frame aerial circuit is given below.

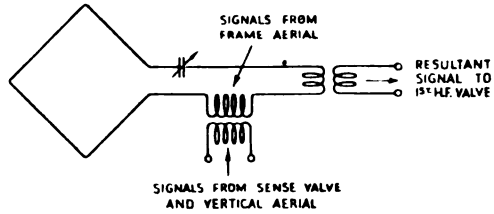

FIG. 2.

If the valuers of signal intensity and orientation of the frame aerial are plotted for any given station, we shall obtain the usual figure of eight polar diagram, with the line YOY corresponding in direction to the direction of the station relative to the frame. Minimum signal strength will occur, of course, when the frame is at right angles to the direction of the station.

In the case of the vertical aerial, the polar diagram will be a circle. Suitably combining the signal amplitudes from these two aerial systems, we can obtain a cardioid. This is the condition used on a direction finder to obtain the sense of a station as distinct from its direction. It is used on the R.G.12 receiver, however, to eliminate interference from unwanted signals.

If we take the case of a sinusoidal signal inducing an E.M.F. of maximum amplitude A in the open aerial, and of A′ in the frame, and arriving at an angle θ to the normal to the frame, we shall see that the E.M.F. induced in the open aerial is always in phase with the wave and can be represented by

$$A \sin wt.$$

The E.M.F. induced in the frame is in quadrature with the above and can be given by

$$A' \sin \theta \cos wt.$$

Referring to Fig. 1, the induced E.M.F. from the open aerial coupling coil to the frame coils will be in quadrature with this last, provided the reactance of the aerial is negligible compared with its resistance, and will be represented by

$$- B \cos wt.$$

The orientation of the frame for complete extinction of the signal will be given by the relation

$$A' \sin \theta - B = 0$$

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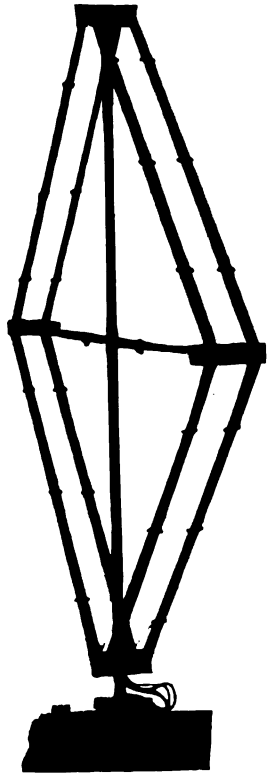
In general this will give two values for 0, but these two will become identical when $A' = B$.

It will be seen from the above that to obtain only one minimum it is necessary to arrange that the E.M.F. induced in the frame aerial coupling coils from the open aerial signal shall be equal to that already existing in these derived from the frame.



Frame Aerial for R.G.12 Receiver showing Variable and Fixed Tuning Condensers on Base.

The vertical aerial coupling valve is employed to reduce the size of vertical aerial needed to give the above condition.

The resultant signal then passes into the first high frequency magnifier. The grid circuit consist of two coils, astatically coupled, into one of which the input coil from the frame aerial circuit is coupled. This grid circuit is tuned by means of a ·001 mfd. variable square law condenser and three fixed condensers, which can be plugged in or out. Resistances are placed in the grid circuit to prevent spurious oscillations or squiggers occurring. The valve is supplied with grid negative to enable it to work at the correct point on its characteristic.

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The anode circuit consists of two astatically coupled coils which are arranged so that one coil couples into the correspondingly wound grid coil and the other couples into the second grid coil. The sketch below makes this clear. H.T. is supplied to the centre point of the anode coils, and the neutrodyne condenser is taken from that end of the coil remote from the anode. This is the usual scheme of neutralising a valve. The grid circuit of the next stage of high frequency magnification is similar to the previous one, with the exception that the grid coils are centre tapped to G.N. to make the high frequency potentials on the grid winding symmetrical with respect to those on the anode winding.

After passing through the second stage of high frequency magnification, the signals are rectified in an anode-bend rectifier with tuned grid circuit and a coupling coil which is coupled into the local oscillator which serves to heterodyne the incoming continuous wave signal. This oscillator is of standard design and requires no special description.

The anode bend method of rectification is used in preference to cumulative grid rectification because no signal, however strong, can block the grid and thus render it insensitive for a time to further signals. In long distance reception, when much static or atmospherics are sometimes experienced, this consideration is of the utmost importance.

The rectified signal next passes through two stages of note filters. These, as we have said, are simply tuned transformer-coupled amplifiers, with both grid and anode coils astatically coupled, and with grid circuits tuned by means of a fixed condenser to a frequency of 1,200 $\sim$. This frequency is chosen as being very suitable for aural reception. An ordinary note magnifier, transformer coupled with an Ideal 6 : 1 transformer, serves to amplify further the signals, and these are taken from the anode of the last valve through a step down transformer to the telephones.

Provision is made in the set to enable either none or one or two of the note filters to be used. This is achieved by jack plugs in the anode circuits of the respective valves. Terminals are provided in the anode circuit of the rectifier to insert a galvanometer to enable the exact behaviour of the valve to be noted. In this way the value of G.N. for the valve can be found which will give the best rectification.

Blocking condensers are provided where necessary to promote stability and to obviate battery noise, etc., and a bye-pass condenser is provided after the anode of the rectifier to shunt all high frequency currents which may have been carried that far. The presence of these currents would, of course, render extensive low frequency amplification impracticable.

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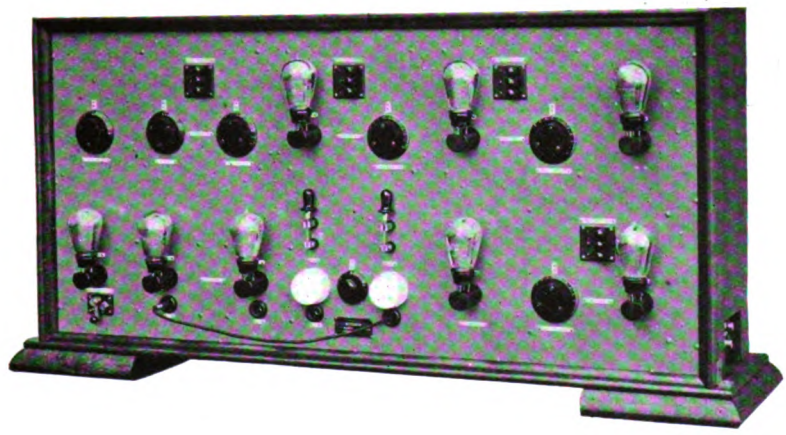
All the various units for the set are effectively screened by copper boxes, and are mounted on wood bases which are screwed on to the aluminium panel which forms the front of the set. The valves are carried on ebonite holders which project some three inches from the front of the set. The valves used are D.E.5's and D.E.5 B's. D.E.5 B's are used for the high frequency magnifiers and for the sense valve, and D.E.5's for all other purposes.



R.G.12.

Tuning throughout the set is performed with ·001 mfd. square law variable condensers, and each tuned circuit has, in addition, three fixed mica dielectric condensers of ·0008, ·0016, and ·002 mfds, which can be plugged in or out to obtain the various ranges. Tuning is readily carried out by means of the calibration charts, but will be found extremely sharp. This selectivity, combined with the directional properties of the receiver, and the system of note filtering employed, is one of the main features of the set, for however loud a signal may be received, it is the relative loudness of the signal over others that may be received at the same time which determines its readability by ear, or its usefulness for recording purposes. Hence it is just as important to cut out unwanted signals as to receive those that are wanted. The two note filters incorporated in the receiver ensure this, for a small change in frequency of an incoming signal will result in a very large change in the rectified and heterodyned signal, and the tuned circuits in the note filters will effectively stop these unwanted signals being passed through.

The selectivity of the R.G.12 receiver is such that two signals of equal intensity and from the same direction, can be separated if their frequencies differ by 120~ only.

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The recevier is primarily designed for aural reception of signals, but can easily be adapted for recording work.

The R.G.12 receiver is made in three editions covering a waverange of from 1,600 metres to 25,000 metres. These are

R.G.12	.. .. ..	10,000—25,000 metres.
R.G.12a	.. .. ..	4,000—10,000 ,,
R.G.12b	.. .. ..	1,600— 4,000 ,,

The wavelength ranges have been so chosen as to include most of the stations transmitting Press bulletins.

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MARCONI NEWS AND NOTES

THE MARCONI MULTIPLEX SYSTEM
COMBINED TELEPHONY AND TELEGRAPHY.

Receiving Room at Bridgwater Beam Station showing Marconi-Mathieu Multiplex Receiver on left, and two Standard Beam Telegraph Receivers on right, with landline table.

SIR ROBERT DONALD, G.B.E., LL.D., who was Chairman of the British Imperial Wireless Telegraph Committee, wrote an important special article in the *Daily Mail* of March 4th, describing the duplex telephone test carried out between Canada and England on March 1st. This demonstration took place at the Beam Receiving station at Bridgwater in the presence of Sir Basil Blackett, K.C.B., K.C.S.I., Chairman of the newly organised Imperial Communications Company, Mr. David Sarnoff, Vice-President of the Radio Corporation of America, and the Rt. Hon. F. G. Kellaway, P.C., Managing Director of the Marconi Company.

The telephone conversation, which took place with the Vice-President of the Canadian Bell Telephone Company and the Vice-Chairman of the Canadian Marconi Company, who were in Montreal, was perfect, and Sir Robert Donald described the occasion as marking a "revolution in wireless telephony—another triumph for the inventive geniuses of the Marconi Company."

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Sir Robert, continuing his description, said :

" We were witnessing the successful demonstration of transmitting speech over a distance of more than 3,000 miles on the same wave length simultaneously with two wireless telegraph messages. While we were using the desk telephone in the office of the station, the tape was running off written telegraphed messages in the operating room at the rate of hundreds of words a minute. These were being relayed to London without interruption.

" The invention is a unique combination of efficiency and economy. The system may be incorporated in all ' Beam ' stations on the Imperial Chain, avoiding the necessity for erecting new stations for telephonic communication.

" The secret of the system is in reception. Up to now it has not been possible to use the same station for wireless telegraphy and telephony.

" When messages are transmitted from Montreal simultaneously on the same wavelength they are sorted out on reception. While the Morse code messages continue without further assistance, the spoken message is regulated by other inventions, in particular by a Gain controller and an " echo suppressor."

Efficiency and Economy.

" The advantages of the Marconi-Multiplex System, as it is called, are many," Sir Robert continued. " It is more efficient and incomparably cheaper. It does not involve the reconstruction of stations. It enables a short wave to be used. There is great economy in power, and there is almost complete secrecy. No one could have listened to our conversations except through a similar installation. Part of a message could be heard, but the whole conversation could not be picked up.

" What is being accomplished on the Canadian circuit can be carried out between other parts of the Empire. Already an apparatus is being made for the South African Beam station. The universal adoption of the system would enormously cheapen telephonic communication throughout the Empire.

" These new developments, which have now been brought to a commercial stage, have taken eighteen months to mature. They will make the British Empire more independent in its means of communication, and once all the home and overseas Beam stations are equipped with new reception apparatus conversations between England and the Dominions, will become almost as usual as they are to-day between London and the Continent."

This opinion of the Marconi-Multiplex System from an independent observer such as Sir Robert Donald, whose experience as Chairman of the Imperial Wireless Telegraphy Committee makes his views of unusual weight, will be of the greatest value to all who are interested in the establishment of wireless telephone services over long distances.

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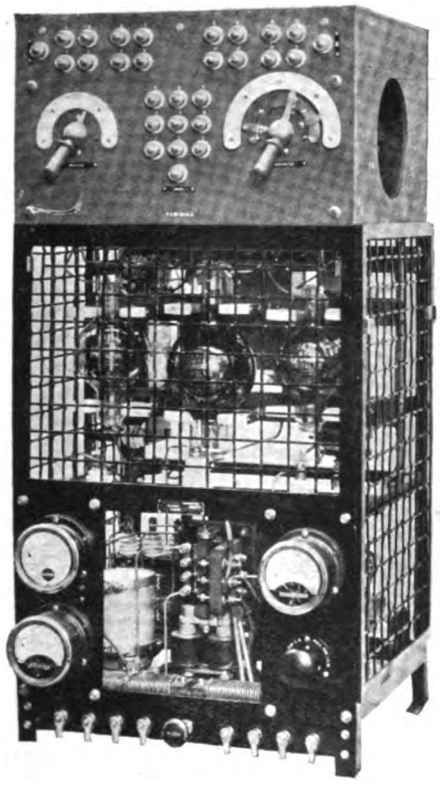
Wireless for Railway Steamer Services.

The value of wireless in maintaining time schedules and promoting efficient organisation on regular steamer services which are linked up with railway routes is becoming more and more widely recognised in view of the modern demand for rapid and efficient international transport services.



Marconi Type M.C.13 1½ kw. Transmitter as ordered for the London & North Eastern Railway Company's Steamers.

The London and North Eastern Railway Company, one of the "Big Four" British railway systems, has placed an order for its three new steamers for the Continental route, *via* Harwich-Hook of Holland, to be equipped with the latest type of Marconi Valve Transmitting apparatus. At the railway company's coastal wireless station at Parkeston a similar installation is being fitted, so that the steamers will be able to maintain contact with the railway authorities throughout the North Sea crossing, and also when they are in harbour on the other side.

Reduction of Interference

The North Sea is one of the world's busiest wireless traffic areas, and in consequence, special attention has been given to the reduction of interference on these railway steamer wireless services.

The Interrupted Continuous Wave (I.C.W.) method of signalling will be used, the employment of valve transmission instead of the old spark method of signalling, having many obvious advantages. Interference, even on the same wavelengths, can be reduced considerably; and arrangements are also made so that the power of transmission can be controlled down to about one quarter of the full range of the installation, a practical feat of great convenience for communication over short distances only, and also for reducing the amount of possible interference with other wireless services.

If the distant receiving station should complain of interference, an alteration in the speed of the generator of these transmitters will produce an alteration in

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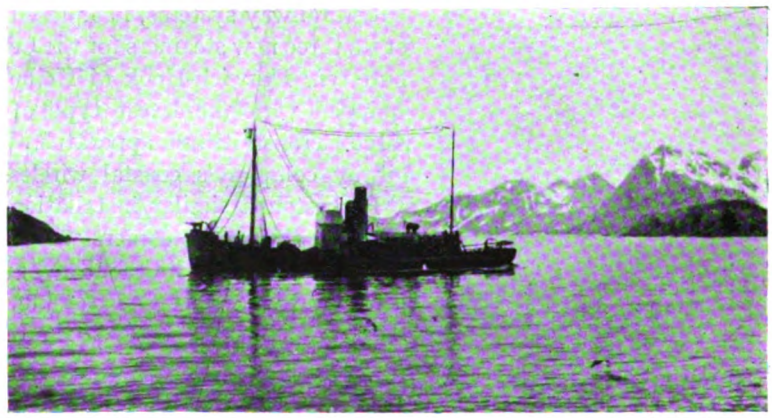
the tone of the transmitted signals. This can be made sufficiently distinctive from the interference signal to allow communication to continue without delay.

The full power of the transmitters, which are known as the Marconi Type M.C.13, is 1½ kw., and they will work on wavelengths between 600 and 800 metres.

Wireless Direction Finding in the Antarctic.



Whaler of Southern Whaling and Sealing Company in South Georgia Harbour, fitted with Marconi 500 watt Wireless Telephone Installation.

The value of the wireless direction finder as an aid to navigation on all the seven seas is fully recognised to-day, but the fact is not usually appreciated that in some parts of the world the wireless direction finder provides the only reliable means of taking relative bearings.

Observations previously made at the Poles have shown that as the magnetic North and South are approached the ordinary compass becomes highly erratic, which on many occasions has proved a considerable obstacle to exploring parties. Until the science of wireless direction finding attained its present pitch of practical perfection there was no means of obviating the difficulty of obtaining bearings when visibility was bad or doubtful. With this instrument, however, modern explorers are secured against the great dangers of getting lost as their ships approach the Poles.

Captain Byrd, whose scientific expedition in the Antarctic, with an aeroplane and the two base ships " City of New York " and the " Eleanor Bolling," has pene-

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trated far into the Antarctic, has in a recent report made special mention of the value of his wireless direction finder. His report is as follows :—

> " Through the aid of radio direction finding equipment, with which both of the expedition's ships are equipped, Captain Brown picked up the whaling steamer ' C. A. Larsen ' at a time when all the regular compasses on both the ' City of New York ' and the ' Eleanor Bolling ' were rendered completely useless because of the proximity of the magnetic pole."

Captain Byrd has also found his wireless telephone equipment of great value during his present expedition, as it has enabled him to keep in touch with the Antarctic whalers and whaling stations fitted with Marconi Wireless telephone apparatus. The whalers have been equipped with Marconi ½ kw. telephone sets, with which they have on occasions been heard over distances of more than 2,000 miles. Normally communication is maintained between whalers and the factory ships and the whaling station at St. Georgia up to distances of 700 and 750 miles. A number of Marconi Direction Finders have also been fitted to these craft and have been found invaluable in assisting the navigators to return quickly to the base with their catch, and in emergencies to steer direct to other members of the fleet.

Before the advent of wireless in Southern Waters the movement of whalers from the Mother Ship frequently had to be considerably restricted owing to the unreliability of compass bearings, and even so it would sometimes be found that one whaler would discover more whales than it could deal with while others were searching in vain.

Marconi Wireless Telephones and Direction Finders have obviated both these difficulties.

Successful Transatlantic Test with T.N.7 Transmitter.

In a recent issue of THE MARCONI REVIEW a description was given of the Marine Type T.N.7 Short Wave Transmitter which had been specially designed for installation on all classes of naval vessels.

One of a batch of these transmitters was completed a few days ago and temporarily installed in a hut near the Marconi Works at Chelmsford, Essex, for the purpose of carrying out long distance communication tests.

Arrangements were made with Transradio Internacional Company of Buenos Aires to listen for a preliminary test transmission on the night of February 26th/27th. This test was duly carried out, and a few hours later a wireless message was received from Buenos Aires reporting that signals on both continuous and interrupted continuous waves were quite readable.

These very successful preliminary tests were made on a wavelength of 36 metres, the aerial current of the T.N.7 transmitter being 250 watts.

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On Friday evening, March 1st, 1929, an official test was arranged with the Transradio Internacional Company of Buenos Aires, and advantage was taken of the occasion to invite the official representative of a foreign navy, who was on a visit to London, to attend the demonstration.

On this occasion very successful transmissions were carried out to Buenos Aires, and the naval representative who was present was able to transmit messages to his friends in South America, a reply being received from one of them during the course of the demonstration, stating that reception was extremely satisfactory.

The tests were concluded by operating the transmitter for several hours on an overload of 30 per cent. without the apparatus showing any sign of overheating.

The results of the above tests over a distance of 6,000 miles proves the value of this transmitter for long distance communications on cruisers and other naval vessels which operate at great distances from their base.

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No. 7

THE MARCONI REVIEW

April, 1929

CONTENTS

THE MARCONI-MATHIEU METHOD OF MULTIPLEX SIGNALLING - - - - - - PAGE 1

MARCONI RECEIVERS FOR TIME SIGNALS AND PRESS BULLETINS - - - - - - „ 8

THE MEASUREMENT OF SIGNAL STRENGTH - „ 13

THE CALIBRATION AND CONSTRUCTION OF A STANDARD FREQUENCY METER - - - „ 18

MARCONI NEWS AND NOTES—

AIR ROUTE TO INDIA - - - - - „ 29

BROADCASTING STATION FOR SWEDEN - „ 31

BROADCASTING STATION FOR YUGO SLAVIA „ 32

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THE MARCONI REVIEW

No. 7. *April, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

THE MARCONI-MATHIEU METHOD OF MULTIPLEX SIGNALLING

GENERAL DESCRIPTION

In the March number of THE MARCONI REVIEW *a short preliminary description of the "Marconi-Mathieu Multiplex System" was given.*

In the following article a more complete and detailed account is given of the above system, and the general principles on which the transmitter and receiver work are described in full.

A technical description of the apparatus will follow at a later date.

THIS system enables both telegraphy and telephony to be carried on simultaneously at the same stations using the same aerial, feeder system and plant without detriment to the quality of the telephony or telegraphy.

Both services, telephony and telegraphy, work together without interference with each other.

The extra cost of adding the equipment to an existing Beam Station or to that of an ordinary simplex new installation, is unimportant compared with the heavy cost which would be entailed by erecting separate stations capable of being used for one of the services only.

The present available standard apparatus provides for one telephone circuit and two telegraph high-speed channels. The commercial speed of these telegraph channels is between 100 and 200 words. The telephone channel enables communication from subscriber to subscriber and incorporates voice operating devices effectively preventing echo and singing.

Transmitter Modulation.

For Multiplex working the standard transmitter is equipped with a modulating circuit consisting of a sub-sub-modulator, a sub-modulator, and two main modulating

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valves working on the anode choke modulating system. This additional equipment is in every point identical to a Broadcasting modulating equipment, and provides for a 90 per cent. distortionless modulation of the transmitter. In these conditions the normal rating of the transmitter is 10 kw. to the anode of the main amplifier and 10 kw. to the main absorbing valve. With an even distribution of the total modulation, each channel will then modulate the transmitter to the extent of 30 per cent.

The carrier power of 10 kw. is common to all three channels and therefore, for comparison purposes, the power of each channel corresponds to that of a 10 kw. simplex transmitter modulated 30 per cent., and the effect at the receiving end, therefore, corresponds to these conditions.

For the purpose of avoiding interference between the telephone and telegraph channels, and also to decrease the power required to convey intelligibility in the telephone channel, which is mainly due to the L.F. component of the speeds, the telephone channel frequencies are limited between 400 and 3,000 cycles. The first telegraph channel is obtained by keying a 7,000 channel generator and the second telegraph channel by keying a 9,000 generator, all the frequencies are superimposed and used as total modulation power of the transmitter.

It is obvious that under these three simultaneous modulations the transmitter radiation is as follows : the carrier wave ; two waves corresponding to the upper and lower side bands produced by the 9,000 cycles telegraph channel modulation ; two waves corresponding to the upper and lower side bands due to the 7,000 cycles channel modulation, and two side bands of modulation caused by the telephone channel.

Allowing a 1,000 cycles margin for adjustment on either side, such a multiplex transmitter occupies an effective band of 20,000 cycles.

The auxiliary Multiplex transmitting gear consists of three small valve generators adjusted to transmit respectively 9,000, 7,000 and 1,000 cycles. The first two are used for telegraph working, and the 1,000 cycles generator for the adjustment of the telephone channel, but this could also be used as a third telegraph channel in replacement of the telephone channel.

Keying on Telegraphy.

The system used for the keying of these generators secures an equal time of spacing and marking current at all speeds, using both contacts of a relay set on its neutral mechanical bias. The circuits provide for an output free from key-clicks and harmonics, and are covered by patents.

Means are provided for the adjustment of the output of these generators and also to check them without causing any interference. The normal output of each of these generators is 1 mw. into an impedance of 900 ohms, which has been chosen arbitrarily as zero level for all the adjustments.

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The adjustment and distribution of the modulation between the channels is

obtained by working the output of these three generators into a composite unit through calibrated resistance networks.

It is obvious that it is not necessary to make use of these three channels always, and that if desired one single channel using the complete modulation can be used, or if traffic conditions do not justify the use of two telegraph channels at certain hours,

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one of the telegraph channels can be switched off, leaving a 45 per cent. modulation for the telephone and 45 per cent. modulation for the telegraph channel utilized, or any of the distribution of the 90 per cent. modulation between these two channels.

Of course, normally the 1,000 cycles channel is replaced by the telephonic modulation, and to that effect the auxiliary apparatus also provides for filters limiting the speech channels frequencies between 400 and 3,000 cycles, and a neon-tube amplitude limiting device preventing over-modulation of the telephone channel, by accidental shouting or mistakes made in handling the telephone landlines circuits.

At first sight it might appear that the result obtainable on the telegraph channel, with 10 kw. carrier modulated at 30 per cent., would be inferior to that obtained with a transmitter working simplex at 18 kw. input, keyed at the usual 100 per cent. absorption method ; full power being sent for marking and no radiation at all in spacing, but our experience has proved, over and over again, that the telegraph multiplex channel of the new system is at least as reliable and even often more reliable than the old simplex system.

Elimination of Fading.

This is due to the pronounced anti-fading property of the new system, which is based on the well-known selective fading properties observed nearly at all times in all our commercial short wave communication services.

By selective fading is meant the fact that the same messages sent simultaneously by two transmitters working with small differences of frequencies, practically never fade simultaneously.

" Fading " is used in this case to mean the rapid phenomena observed continuously during the normal conditions of propagation, and not the complete fading of the signal due to the action of magnetic storms.

The modulation of the transmitter at 7,000 cycles or 9,000 cycles is equivalent to the sending of the same messages by two transmitters working 14,000 or 18,000 cycles apart, and assuming a steady and constant carrier, it is sufficient that one of these side bands exists to get the signals. In effect, the carrier itself is affected by fading and when fading to nothing, or to a very small value, there would be no signal after detection, even if the two side bands of the telegraph channel should be strong at the same instant.

Treatment of Side Bands and Carrier.

To avoid this, in the Marconi-Mathieu Multiplex System, the transmitted carrier wave is suppressed at the receiving end, then reintroduced by means of a steady constant generator of exactly the same frequency.

The anti-fading properties of the system are strikingly demonstrated when using the multiplex receiver, which permits an independent reception of either the upper

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side bands or the lower side bands of either of the two telegraph channels, thus allowing a comparison of the results obtainable on one of the side bands alone with both used simultaneously.

The Receiver.

The multiplex receiver is of the double heterodyne type and involves many special and new features, which are covered by patents.

It is characterised by the fact that an harmonic of the generator reintroducing the suppressed carrier is used as second heterodyne between the first and second intermediate band filter amplifiers, and in such a way that the resulting beat frequency of that harmonic, with the first new carrier wave due to the action of the first heterodyne of the original carrier, corresponds exactly to the fundamental frequency of that generator, thus permitting a zero beat method of adjustment for the whole receiver, involving only the adjustment of the first heterodyne.

This invention renders the system commercial and converts an otherwise hopelessly complex handling into simplicity itself.

Key-clicks, due to the telegraph channels, have been completely eliminated from the telephone channel, by separating, before detection, the telephone channel and the telegraph channel at high frequency, after they have been heterodyned for the first time and amplified together.

After the second frequency change, the upper side bands and lower side bands of the two telegraph channels are separated and amplified separately. The suppression of the carrier occurs also at that stage.

The separation of the telegraph channels, both in each of the side bands, is effected after the reintroduction of the carrier, by means of band filter amplifiers, which width of band is sufficiently large to allow a speed of 300 w.p.m. and the adjustment of the zero beat without creating interference.

The types of band filter amplifiers are the same as those used for the standard beam receivers ; they have the advantage of having an extremely small noise level and are capable of handling, without distortion or saturation, a very large amplitude of signal.

The adjustment of high frequency amplification of the receiver and that of the low freqency amplification of the telephone channel, is automatic and is effected by the variation of an attenuating distortionless network controlled by mechanical relays.

These automatic devices are remarkably reliable. They require very little attention and keep their adjustment for months on end ; they possess the enormous advantage of introducing no reaction in the circuits, no extra noise level, no distortion and no change in the characteristics of the valves.

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The telegraph direct current bridge and limiting device are in every respect similar to that of the standard beam telegraph receivers, which are giving such good service on all the Marconi Beam Stations. They only differ in the fact that they provide for the combination of the upper and lower side band signals of each channel.

Description of the Receiver.

The receiver consists of two stages of H.F. amplification amplifying together all the original waves, followed by a first frequency change circuit. The heterodyne of this circuit has been made very stable by the use of a special driving circuit working into a separating valve. The output of the modulating valve of this circuit works into a four-stage band filter amplifier, which middle frequency is 180,000 cycles with a band of 10,000 on either side of that frequency.

The separation of the telephone and telegraph channels is started by means of coupling valves preventing reaction between the circuits and working respectively, one into a similar 20,000 cycles band filter for the telegraph channels, and the other into two very selective stage filter amplifiers having a band of only 3,000 cycles on either side of the new carrier wave and securing the separation of the telephone from the telegraph channel.

The telephone detectors are diode valves working in push-pull and without high tension. The circuit is such that all possible induction originated by the auxiliary apparatus of the telegraph channels, as the mechanical relays, check undulator, sounders, etc., are effectively balanced before they reach the input of the L.F. amplifier.

This detector circuit also provides for the separation of the A.C. alternating current component from the direct current component, due to the demodulation process. The direct current impulses are smoothed by filters, then amplified by a special direct current amplifier, which output is used for the working of the relays actuating the artificial lines of the automatic gain controls.

The L.F. amplification or receiving repeater consists of two stages of amplification having a total gain of about 40 T.U. and a maximum distortionless output of plus 10 T.U.

The gain of the two stage direct high frequency amplifier runs from 5 to 20 T.U. according to the wavelength used.

The maximum gain of the H.F. intermediate amplifier, common to all channels, is about 80 T.U.

The automatic device controlling the H.F. amplification operates on the input of the coupling valve mentioned above. The description of this automatic system will be given later.

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Returning to the telegraph channel we will repeat that the output of the coupling valves of the first intermediate band amplifier is working through an intermediate band filter into the grid circuit of the second modulating valves, where all the waves are made to beat again with the 5th harmonic of the reintroducing carrier generator.

The output of this modulating valve works into filters, which purpose is to separate the upper side bands and the lower side bands of the telegraph channels ; to suppress the new carrier wave and to very strongly attenuate all the frequencies of the telephone channel.

The frequency generated by the carrier reintroducer channel is 30,000 cycles. Its 5th harmonic being 150,000 cycles, it will be seen that when subtracting this 5th harmonic from the 180,000 first new carrier, it reproduces a wave of 30,000 cycles.

The zero beat method consists of coupling simultaneously the input circuit of a detector to the output of the second modulating valve and to that of the carrier reintroducer circuit.

It can be seen that in these conditions when the original carrier is being changed exactly to 180,000 cycles by the action of the first heterodyne, a zero beat note will occur in the output of that detector, thus permitting the adjustment of the receiver.

The upper side bands and lower side bands of the telegraph channels, once separated, are amplified separately by the upper side bands and lower side bands band filter amplifiers which are designed for a width of 3,000 cycles, with a middle frequency of respectively 38,000 cycles and 22,000 cycles.

The gain of these amplifiers is approximately 50 T.U. These two amplifiers are terminated by push-pull detectors where the carrier is reintroduced by means of coupling valves which prevent any back reaction towards the carrier reintroducer generator. The output of these coupling valves work into very loosely coupled low-damping condenser circuits, tuned sharply to 30,000 cycles and arranged to be used as a wavemeter for the adjustment and checking of the frequency generated by the reintroduced carrier generator.

The effect of reintroducing the suppressed carrier is to reproduce the 7,000 and 9,000 cycles modulation impressed on the transmitter on both side band circuits. Their respective separation is then obtained by means of filters associated with the output circuit of the detectors.

The output of these filters works into 7,000 and 9,000 cycles valve amplifiers and are terminated by a final detector valve the D.C. components from which feed the D.C. and limiting circuit of the recording units.

G. A. MATHIEU.

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MARCONI RECEIVERS FOR TIME SIGNALS AND PRESS BULLETINS

II.—R.P.11

In the last issue of THE MARCONI REVIEW, *an account of a receiver—Type R.G.12—for the reception of press messages was given. In this article a description of the Type R.P.11 receiver, which is primarily designed for the reception of time signals, will serve to show in what respects the design of receivers for the above mentioned purposes differ from one another.*

Time signal reception is becoming of increasing use, partly for the synchronisation of widely separated activities and partly for the accurate determination of longitude, etc.

Many stations transmit time signals of great accuracy, and it will be seen therefore that the wireless method of obtaining accurate time signals is far more practicable than any of the older methods and is becoming of almost universal use.

The R.P.11 receiver is sufficiently portable to be used by survey parties and is built in such a way that it can resist extremes of climatic conditions.

THE type R.P.11 receiver has been designed for the reception of time signals from high power long wave stations. The outstanding features of the receiver are as follows :—

1. Portability.
2. Ability to withstand rough usage in any climate.
3. Great selectivity.
4. Low filament consumption.

The receiver itself uses four valves of the D.E.3B type, performing the functions of detector, note filter, note magnifier, and local oscillator respectively.

A phasing unit, separate to the receiver, is also provided to enable directional selection of stations to be more efficiently achieved.

The receiver is intended for normal use with a frame aerial with no earth connection to the set, but terminals are provided for connecting an open aerial and earth. In the latter case the frame must also be connected to the set to complete the circuits. The receiver is far more selective with the frame than with the open aerial, but signals are naturally stronger in the second case.

In the case of cardioid reception with the phasing unit, a vertical aerial has, of course, to be used. This may be of any convenient length, a length of about 30 feet being generally sufficient to give a cardioid diagram.

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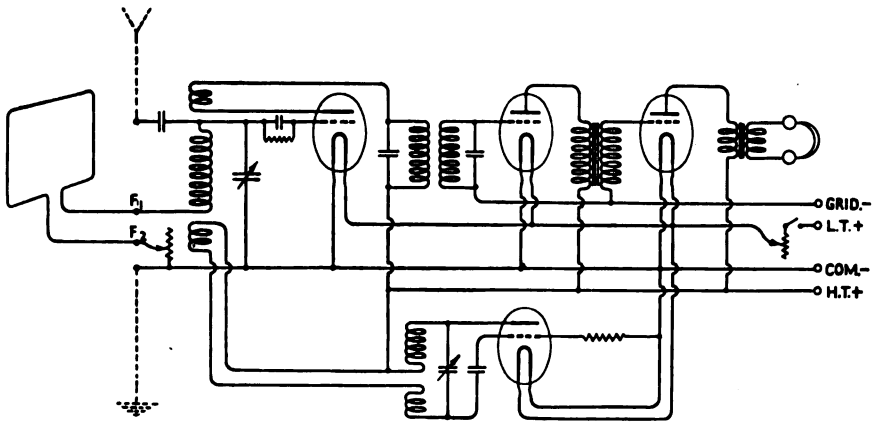
The waverange of the receiver is from 15,000 to 22,000 metres, and this range is covered in two steps. A modification of the R.P.11 receiver has been designed to cover an extended waverange of 10,000 to 22,000 metres, and this is termed the R.P.11a receiver.

The Receiver.

A simplified diagram of the receiver is given below.



The aerial tuning inductance is contained partly in the frame aerial and partly in a coil in the receiver. This coil is provided for the purpose of introducing reaction into the aerial circuit, and also the signal from the local oscillator. Both the reaction coil and the local oscillator coupling coil are fixed rigidly to the aerial coil and the degree of reaction is controlled by a non-inductive helical resistance in the frame aerial circuit. This method of controlling reaction has the advantage of permitting a very gentle " slide in " to reaction and consequently allows reaction to be used to an extent to which it would not otherwise be permissible.

Grid leak rectification is used, and it is found that this does not give rise to any blocking of the rectifier grid as the signals induced in the frame are so small, and no high frequency magnification is used on the set.

Tuning is accomplished on the lower of the two waveranges by means of a ·001 mfd. variable condenser in the aerial circuit, a fixed condenser of ·001 mfd. being placed in parallel with this on the second range. The two ranges are selected by means of a barrel switch which is operated from a handle placed in front of the set.

The note filter stage employs the standard circuit and consists of an air core transformer with its grid winding tuned to a frequency of 1,200 cycles by a mica dielectric condenser of ·01 mfd. capacity.

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The note magnifier is transformer coupled to the preceding stage and is normal in design.

The local oscillator employs the usual circuit, and has its constants so arranged that its tuning condenser keeps roughly in step with the aerial tuning condenser when giving a beat note of 1,200 cycles. The coupling coil to the aerial circuit is taken from the earth end of the local oscillator inductance, and since it consists only of a few turns the coupling to the aerial circuit is purely magnetic, and this fact, combined with the fact that the local oscillator circuit is tuned by varying its capacity only, ensures an equal strength of oscillator signal over the whole of the range. A fixed condenser is switched in for the upper range, the same switch operating both the aerial and oscillator circuits in this respect.

Telephones.

Low resistance telephones are used with this receiver, and these are arranged to have a natural period of 1,200 cycles. In this way a considerable gain in sensitivity and selectivity will result, as the optima of the note filter stage and of the telephones coincide.

The telephones can either be connected directly on to the secondary winding of the transformer, or can be connected in series with the contacts of a chronometer. This last method is resorted to in the case where the " vernier " system of time signal measurements is used. Assuming that the contacts of the chronometer open once a second, and that the chronometer and telephones are in series, the chronometer and time signal would be in step when the dot of the time signal was not heard in the telephones for the first time. If the contacts of the chronometer are arranged to close once a second, the chronometer and telephones will be connected in parallel. Means are provided in the R.P.11 receiver to enable either of these two systems to be employed. In this way it will be seen that very accurate time signal determinations can be made.

Phasing Unit.

So far we have only considered the receiver as used with an open aerial giving a circular polar diagram, or with a simple frame giving a figure-of-eight polar diagram. An external phasing unit is provided for use with the receiver and consists of a coupling valve, coupling coils from the vertical to the frame aerial and an intensity control to enable a correct cardioid diagram to be obtained.

A simplified diagram of connections of the phasing unit is given below, and it will be seen to be almost identical in design to the phasing unit described in connection with the R.G.12 receiver. Two leads are taken from the frame aerial to the phasing unit, where they pass through the two coils coupling into the output coil from the coupling valve. The other ends of the coils are connected to the terminals F1 and F2 of the receiver. The output coil from the coupling valve is variably

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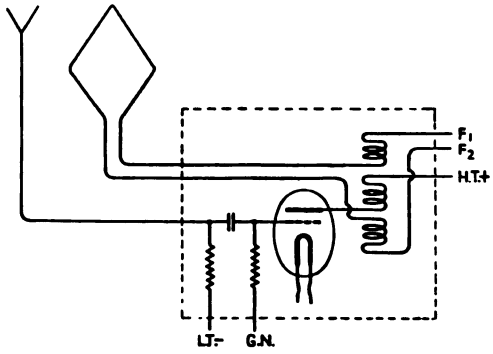
coupled to the two frame aerial coils to enable strength control of the vertical aerial signals to be obtained.

Batteries.

Either two Siemens 66-volt dry batteries are provided for use with the receiver, or eight 15-volt units of the inert type. These batteries are tapped to enable the correct working voltage for the valves to be obtained.



The low tension voltage is 2·8 and the total filament current is ·24 ampere. A dry battery can be used with the set, which is a great advantage where questions of portability are concerned. A filament voltmeter is provided on the front of the set and a red mark is placed on the scale of this at the correct filament voltage.

A grid bias battery of 1·5 volts is required. This can take the form of a very small dry cell.

All the above batteries can be contained conveniently in one box.

R.P.11a Receiver.

This receiver consists of the R.P.11 receiver together with such modifications as have been found necessary to increase the waverange of the R.P.11 to 10,000 to 22,000 metres.

The above waverange is covered in three steps, with ranges of approximately 10,000–14,000 metres, 13,000–18,000 metres and 17,000–22,000 metres. The switching is effected by a barrel switch having four positions, the fourth position being for "Off."

The ranges are obtained in the following manner :—

Range 1. 80 turns only of the standard R.P.11 frame are across the receiver input, and this proportion of the complete frame is tuned by a ·001 mfd. variable condenser.

Range 2. The whole frame of the R.P.11 is used, and this is tuned by the same condenser.

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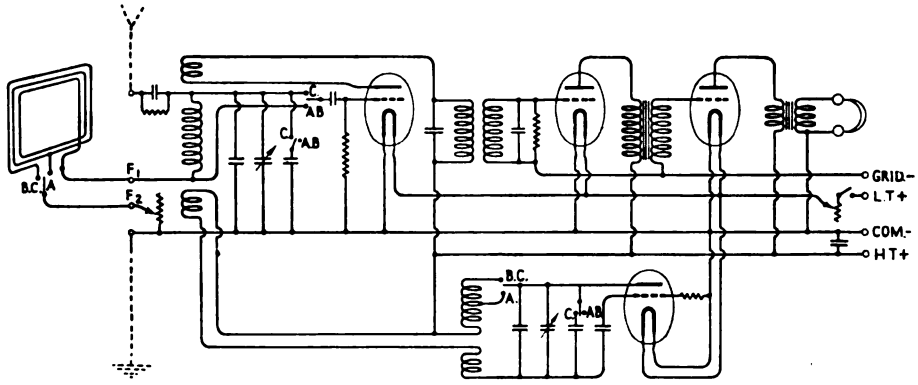
Range 3. An added condenser is placed in parallel with the original condenser.

A compensating device is included in the frame leads to be used in the case of cardioid reception with the phasing unit. This consists of two small added inductances which are placed in the frame leads when using figure-of-eight reception.



These are automatically removed when the phasing unit is plugged into circuit, and serve to keep the calibration of the instrument constant with or without the phasing unit attached to the set.

Selectivity.

The selectivity of the R.P.11 receiver due to the use of H.F. selection and note filtering is such that either of two stations of equal signal strength and lying in the same direction can be separated if their frequencies differ from each other by about 200 cycles per second. At 15,000 metres the receiver can, therefore, separate two stations only 150 metres apart, whilst at 20,000 metres the receiver can select between two stations 270 metres apart.

Equipment.

For convenience of transport the standard equipment is divided into four units.

1. The frame aerial.
2. The receiver.
3. The H.T. battery box.
4. The L.T. battery box and spares.

In cases where the phasing unit is used, this forms an additional item to the standard equipment.

The receiver and phasing unit are contained in separate watertight steel cases in which suitable provision is made for ventilation.

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THE MEASUREMENT OF SIGNAL STRENGTH

HISTORICAL SURVEY

In a later article to be published in THE MARCONI REVIEW *a full description will be given of an instrument designed for the accurate measurement of signal strengths by the Marconi Company.*

Many attempts have been made of late years to evolve scientific means of experimentally determining transmitter field intensities, partly with a view to obtaining experimental confirmation of transmission theories and partly to decide as to the best methods of obtaining as perfect a system of world-wide radio communication as possible.

A brief outline of these attempts is given below, together with a description of one of the first signal strength measurers used by the Marconi Company.

THE first wireless measurements of signal strength with any claim to accuracy were made by Duddell and Taylor in 1905 (Jour. I.E.E. 1905), Vol. 35, p. 321. Wireless Telegraph Measurements, W. Duddell & J. E. Taylor). A Duddell thermo-ammeter was used at the receiver end, and the currents in the receiver aerial were measured.

In 1909 Dr. L. W. Austin began a series of experiments over long distances using a receiver with hot wire and thermo-electric ammeters by which the received currents were measured (Bulletin of the Bureau of Standards, Vol. 7, 1911). The results of these researches led to the final adoption of the semi-empirical Austin Cohen formula :

$$I_R = A \frac{I_s h_1 h_2 e^{-.0015 \frac{D}{\sqrt{\lambda}}}}{D}$$

where
I_R = current in receiver aerial
I_s = ,, ,, transmitter aerial
h_1 = height of receiver aerial
h_2 = height of transmitter aerial
λ = wavelength in kms.
D = distance between receiver and transmitter in kms.

Now Hertz had obtained theoretically the fact that in the case of an oscillator of moment 0 (and of wavelength λ, either the magnetic or electric intensity was given by

$$E \propto \frac{\phi m^2}{r}$$

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where $$m = \frac{2\pi}{\lambda}$$

and r = distance from oscillator to point under consideration,
and it can be shown quite easily that

$$E \propto \frac{\phi m^2}{r} \propto \frac{I_s h_1}{\lambda D}$$

which agrees with the Austin Cohen formula except in so far as the exponential factor is concerned. Hertz, however, assumed perfect conductivity for the earth, whereas in the actual case the earth has a conductivity appreciably differing from infinity.

In 1911—1912 Captain Round and Mr. Tremellen of the Marconi Company carried out a fairly extensive series of measurements on daily and annual variations of high power station signals at various places chiefly in connection with spark transmission.

In 1921 Vallauri published the first results on the use of the comparison method of measuring signals originally suggested and used by Eccles. In the instrument used by Vallauri two frame aerials at right angles to each other were used, one of which pointed in the direction of the received signals. Artificial signals were then induced into the other frame and the real signals compared with them.

Dr. L. W. Austin and E. B. Judson (Proc. I.R.E., Oct. 1924, Vol. 12) suggested a method for the determination of signal strengths using aural comparison of the received signal with an audio frequency signal of known intensity. A 1,000 $\sim$ fork was used as the audio frequency source, and the E.M.F. generated by this was impressed on the telephones by a voltage divider. A thermo-milliameter was used as the measuring device. An open aerial was used for the reception of the signals.

C. R. Englund (Proc. I.R.E., Feb. 1923, Vol. 11) and R. Bonn, C. R. Englund and H. T. Friis (Proc. I.R.E., Apr. 1923, Vol. 11) give an account of the apparatus used by them and consisting of a receiver band filter artificial line, valve voltmeter and local oscillator. The signals from the receiver and the local oscillator were equalised by means of the valve voltmeter, which latter had been previously calibrated. A loop aerial was used. The apparatus is stated to be capable of signal strength measurement of from 3·5 μv/metre upwards.

The National Physical Laboratory published an account of the instrument used by them, in Jour. I.E.E., Apr. 1926, No. 317. In this article will also be found a very complete account of the difficulties of investigations of this nature.

In any signal strength measuring set, what is actually measured is the total E.M.F. in the receiving aerial system. What is required for calculation purposes is

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the actual field strength in microvolts per meter. This transformation involves the measurement of—

1. Either the effective height of the aerial, in the case of a vertical aerial, or
2. The effective area in the case of a frame.

The effective height of any aerial system is very difficult to measure accurately. It would appear therefore that the use of a frame aerial presents the best solution of the problem.

The E.M.F. induced in a vertical aerial is in phase with the E.M.F. of the signal. The E.M.F. induced in a frame due to the magnetic component of the signal is in quadrature with the E.M.F. of the signal. A certain E.M.F. due to "vertical" effect is always present in such an aerial system and is in phase with the signal E.M.F. This introduces an out of phase component of E.M.F. which somewhat complicates the calculation of field strength.

It will be seen therefore that both aerial systems introduce difficulties in calculation of field strength, and we shall point out briefly how these difficulties are, to a certain extent, overcome in the apparatus used by the Marconi Company for the determination of signal intensities.

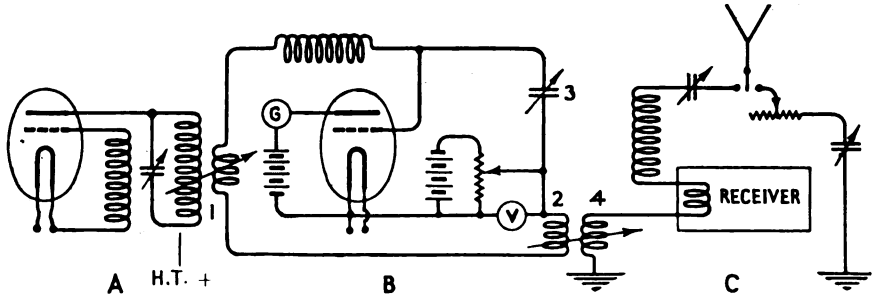

FIG. 1.

The instrument developed and used by the Marconi Company in 1921, while agreeing in some respects with Vallauri's apparatus, differed in many others. The results obtained with it were so consistent and helpful however, that a brief description is given below.

A diagram of connections of the signal strength measurer is shown above (Fig. 1). The method consists essentially in providing an artificial continuous wave signal of the same frequency as the signal to be measured, the intensity of which can be varied over wide limits and measured. This artificial wave signal can be introduced into the receiver aerial or into a dummy aerial having the same electrical constants.

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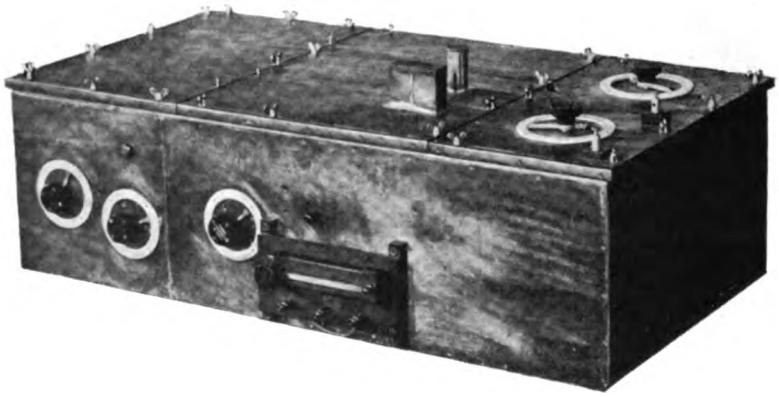
The strengths of the received signals in the dummy aerial caused by the artificial signal, and of those in the aerial caused by the incoming signal, are equalised. The E.M.F. induced in the dummy aerial can be calculated and will give the E.M.F. of the real received signal.

The instrument measures, therefore, the intensity of E.M.F. induced by the signal in the aerial used. If the effective height of the aerial is known it is quite a simple matter to calculate the electric field strength in the incoming wave.

Referring to Fig. 1. The oscillator A is a simple tuned anode oscillator capable of wide frequency adjustment. A variable coupling coil (1) enables signals of the required voltage to be applied to the grid of the slide back valve. The current in



the coil (2) can be calculated if the voltage across the condenser (3) is known, this voltage is given by the reading of the slide back voltmeter, when the following relation holds :

$$I_{max} = C\, p\, V_{max}$$

where

I_{max} = required current
C = capacity of (3)
p = $2\pi \times$ frequency
V = voltmeter reading

The artificial E.M.F. is then induced into the aerial circuit by means of the coil (2). The mutual inductance between (2) and (4) was measured on a low frequency method and checked at high frequencies.

In terms of the known quantities the E.M.F. induced in the aerial could be calculated from the formula

$$E = \frac{2{,}515\ MCV}{\lambda^2}$$

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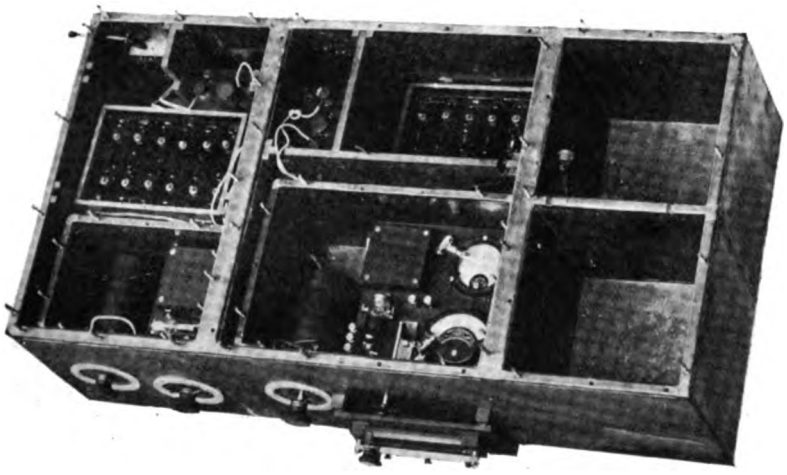
where

M is in microhenries
C is in microfarads
V is in volts
λ is wavelength in metres



Hence the E.M.F. induced in the dummy circuit or aerial, which is made equal to the E.M.F. induced by the signal in the aerial, can be calculated and the signal intensity found.

The two photographs show external and internal views of the apparatus, and the care taken in the screening, etc., of the components can be seen on reference to these.

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THE CALIBRATION AND CONSTRUCTION OF A STANDARD FREQUENCY METER

In 1923 the Marconi Company decided to improve their Laboratory Standard Wavemeter, and to this end certain experiments were carried out on the measurement of high frequencies and also on mechanical details for the instrument, which were finally embodied in the finished designs.

The following article deals briefly with the design and construction of the wavemeters finally adopted, together with an account of the method of calibration by alternator which is used for all accurate frequency measurements.

The development of the frequency measuring apparatus described below has been carried out by Messrs. T. D. Parkin and H. W. Prattley.

THE Marconi Company now uses as its standard wavemeters two instruments with ranges of approximately $9{\cdot}8 \times 10^3$ to $2{\cdot}7 \times 10^5 \sim$ in 12 ranges for one instrument ; the other $2{\cdot}5 \times 10^5$ to $7{\cdot}1 \times 10^6 \sim$ in 8 ranges.

Description of Instruments.

The first of these two wavemeters consists of 3 inductances, 4 fixed air condensers, 1 variable Laboratory Standard Air Condenser, Valve Detector with batteries, Indicating Galvanometer and Reflecting Galvanometer, and busbars, the circuit being as shown in Fig. 1.

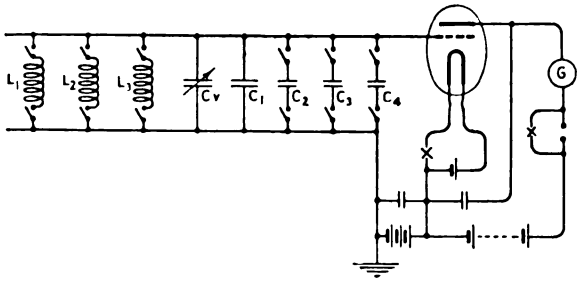

FIG. 1.

The inductances consist of 3 Porcelain Tubes wound with No. 20 Enamelled Copper Wire for a certain fraction of their length.

At each end of each tube is a divided brass band to one section of which the ends of the windings are soldered.

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The large tube has eight segments per band, the second six segments per band, and the third four per band.

Each segment is insulated from every other segment, the idea being to avoid a short circuited turn at each end of each inductance.

The detail is given in Fig. 2.

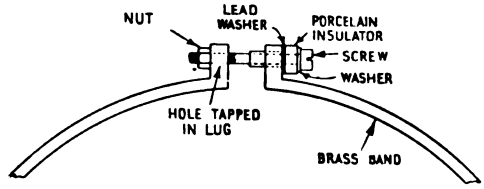

FIG. 2.

Each tube is mounted in a wood and glass octagonal case, and lies with its axis horizontal. The wire of the winding having been soldered to a small lug on one segment of the appropriate brass band, it passes unbroken to a terminal mounted on one side of the case.

The inductances are approximately 17,100, 1,910 and 203 mhys. respectively, and are connected to the fixed busbars by copper straps as required.

The variable condenser is a Standard Laboratory Air Condenser with a 0—180° scale and has a capacity of 0.000255 mfds. at 10° and 0.00396 mfds. at 170°, entirely metal screened, with screen and moving plates earthed.

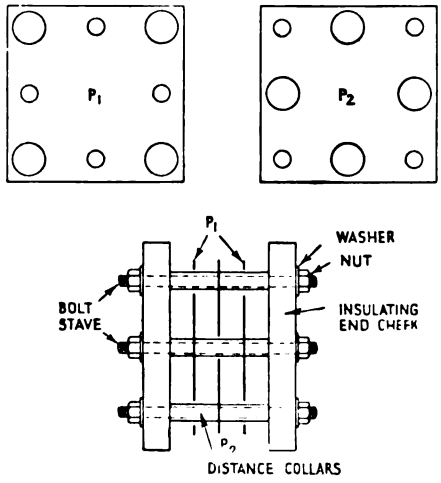

FIG. 3.

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The four fixed air condensers are built up on the Kelvin principle (Fig. 3) and consist of a number of Zinc plates, each held at 8 points and accurately spaced, the whole being held between two ebonite plates. The plates stand vertical and each condenser is enclosed in a sheet steel case.

Terminals are brought through the tops of the cases, the cases are all earthed, and when in use one set of plates is earthed. The first of these condensers is permanently connected in parallel with the variable condenser ; the others are connected as required by removable busbars which are numbered in pairs, Left and Right, to ensure that the same pair of bars is always used when connecting in any particular condenser. It was found necessary entirely to remove the busbars from the unused condensers as errors could be detected if these were just disconnected from one end.

The approximate capacities of the fixed condensers are 0.001386 mfd., 0.003469 mfd., 0.00345 mfd. and 0.00344 mfd.

These give ranges as follows, between certain limits of the variable condenser, the limits not being the same for every range :—

Range	1,	No. 1	Inductance,	4	Fixed,	1	Variable	Condenser	9,878— 11,273	cycles
	2	,, 1	,,	3	,,	1	,,	,,	11,165— 13,298	,,
	3	,, 1	,,	2	,,	1	,,	,,	13,158— 17,153	,,
	4	,, 1	,,	1	,,	1	,,	,,	17,035— 30,380	,,
	5	,, 2	,,	4	,,	1	,,	,,	29,105— 33,219	,,
	6	,, 2	,,	3	,,	1	,,	,,	32,940— 39,234	,,
	7	,, 2	,,	2	,,	1	,,	,,	38,857— 50,615	,,
	8	,, 2	,,	1	,,	1	,,	,,	50,198— 89,938	,,
	9	,, 3	,,	4	,,	1	,,	,,	88,252—100,708	,,
	10	,, 3	,,	3	,,	1	,,	,,	99,912—119,019	,,
	11	,, 3	,,	2	,,	1	,,	,,	118,006—153,742	,,
	12	,, 3	,,	1	,,	1	,,	,,	152,358—273,682	,,

The curve shown in Fig. 4 shows the change in anode current in the standard circuit detector valve in Range 4 as this circuit is brought into tune with an oscillator of suitable constant frequency, and from this can be seen the limit of accuracy to which the standard circuit can be tuned.

It will be seen that by tuning the condenser to 0·1° a change of 8·8 cycles in 21,000 can be detected.

The valve detector circuit needs no comment being of the usual type with about 140 volts H.T. and suitable grid negative to ensure that no grid current flows under working conditions.

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It might here be remarked that it took about 2 years for the condensers to settle to a final steady value.

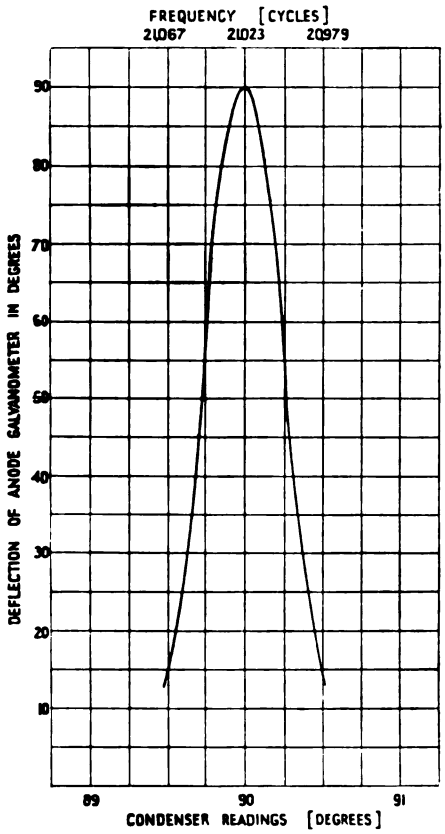

FIG. 4.

The whole is mounted on a 6 legged rigid table bolted to the floor.

The smaller wavemeter is not very different to the large one, but it only has one fixed, and one variable air condenser, and 6 windings all on one tube, spaced, and fitted with the divided bands where necessary.

This wavemeter is entirely mounted on a heavy teak base which is completely covered with copper.

The H.T. battery and grid negative battery are contained in a cavity in the base, and on the lid of this cavity is mounted valve, galvanometer, switches and certain busbars. Heavy conductors come through the lid of this cavity from the H.T. battery and grid negative battery, so arranged that should the battery fail, it can be inspected and renewed without disturbing the lay-out of the circuit.

The variable condenser is again a screened Laboratory Standard Air Condenser with screen and moving plates earthed, and with a capacity of 0.000064 mfd. at 10° and 0.00051 mfd. at 170°.

The fixed condenser is permanently connected in parallel with the variable one and consists of two heavy brass plates, between which are mounted 3 other plates of suitable size, and suitably separated. This condenser is on the Kelvin principle as before, and the outer plates are used as electrodes. The minimum amount of solid insulation is used and the whole condenser is enclosed in a copper lined heavy teak case. Terminals protrude through the top.

The inductances are wound on a former similar to the second one of the big wavemeter, and are 6 in number. Two of these are single turns of $\frac{1}{2}$ in. by $\frac{1}{8}$ in.

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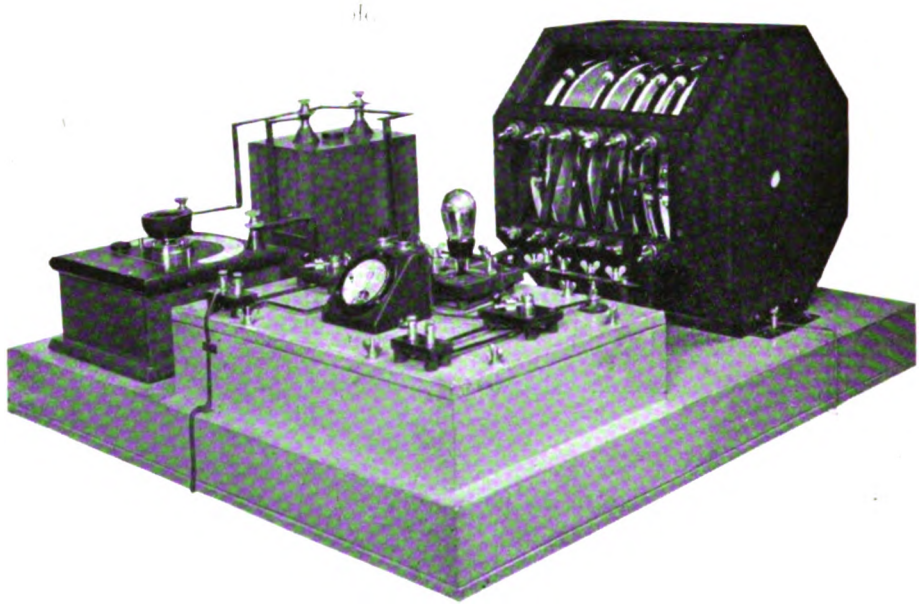
copper ; the other four are 3, 5, 13 and 22 turns respectively of 20 S.W.G. Enamelled Copper Wire. Each winding has two terminals and by strapping and connecting as required 8 ranges are secured.



Short Wave Wavemeter.

The ranges are :—

Range	1	.. ..	253,378— 397,878 cycles
,,	2	.. ..	388,600— 608,520 ,,
,,	3	.. ..	592,886— 914,634 ,,
,,	4	.. ..	874,636—1,369,840 ,,
,,	5	.. ..	1,339,210—2,076,130 ,,
,,	6	.. ..	2,022,930—3,061,220 ,,
,,	7	.. ..	3,045,690—4,958,690 ,,
,,	8	.. ..	4,360,570—7,177,030 ,,

A characteristic curve of Range 8 is given in Fig. 5, for a condenser reading of 90°, and it will be seen that mistuning by 0·1° gives rise to an error of 1,530 cycles in 5,349,500 which corresponds to an error of 1 in 3,500.

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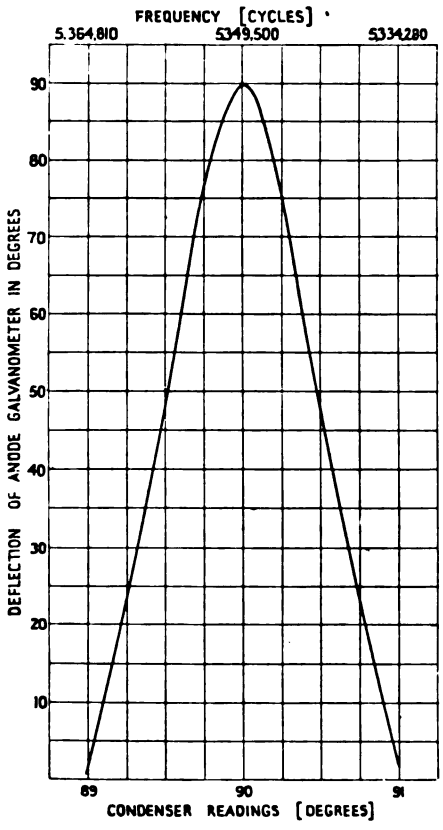

FIG. 5.

Method of Calibration.

The calibration has been done by the aid of a steady running alternator as follows :

A H.F. oscillator, a L.F. oscillator, a detector circuit with a multiple note magnifier terminating in a relay circuit, two recorders, a standard clock, and the alternator have been installed.

The complete diagram of connections is as shown (Fig. 6).

The H.F. oscillator is started and the detector and wavemeter tuned to it, by observing the galvanometers, the grid of the detector valve being slid well back to negative.

The couplings must be of such looseness that when tuning any one of these 3 circuits, no detuning of the others occur. This necessitates the use of a powerful H.F. oscillator far removed from the other circuits.

The L.F. oscillator is then started and is so tuned that one of its harmonics is approaching the frequency of the H.F. oscillator. The coupling K is adjusted to a minimum working degree. The tuning of the L.F. oscillator is then continued and the coupling again adjusted until after repeated tuning and adjustments a multiple of the L.F. oscillator frequency is in step with the H.F. oscillator and the L.F. signal is heard as a pure note at T, the telephone. If the frequency of the L.F. oscillator can now be measured, and multiplied by the correct harmonic, it will give the frequency of the H.F. oscillator. This is done as follows :

The L.F. oscillator is calibrated to a medium degree of accuracy in cycles per second. The alternator which is in another part of the building, removed from the measuring apparatus, is run up, and a small choke connected to the A.C. supply is presented to one or other of the transformers of the multi-stage Note Magnifier. This will give rise to a beat note between the received L.F. signal and the alternator, which will be heard in the telephone, and if strong enough will operate relay R_e.

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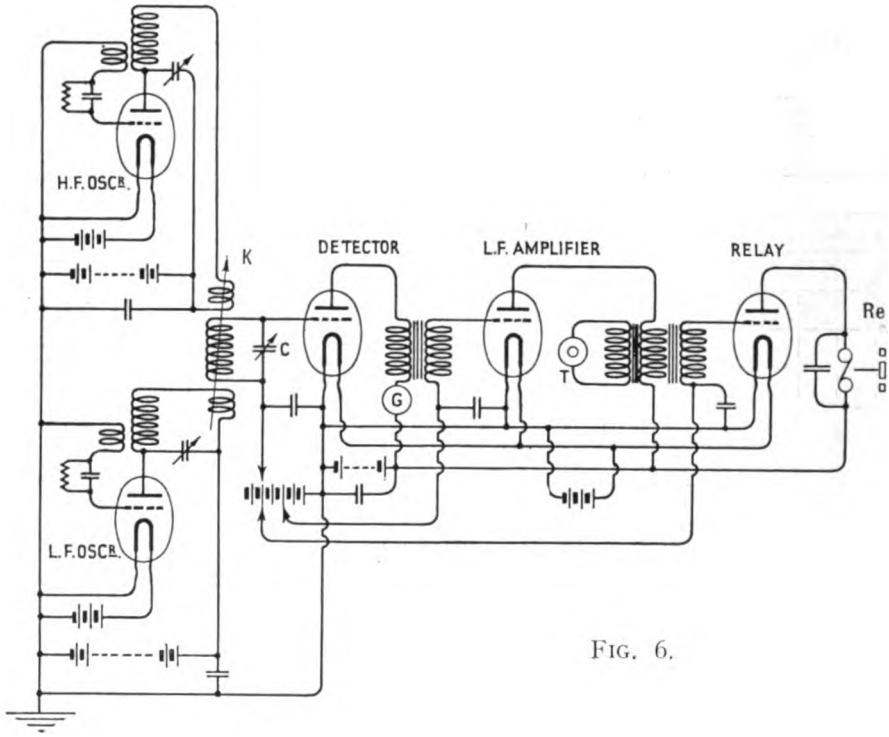

FIG. 6.

It is imperative to know if the alternator frequency is higher or lower than that of the L.F. oscillator. A rule is made of running the alternator a few cycles slower

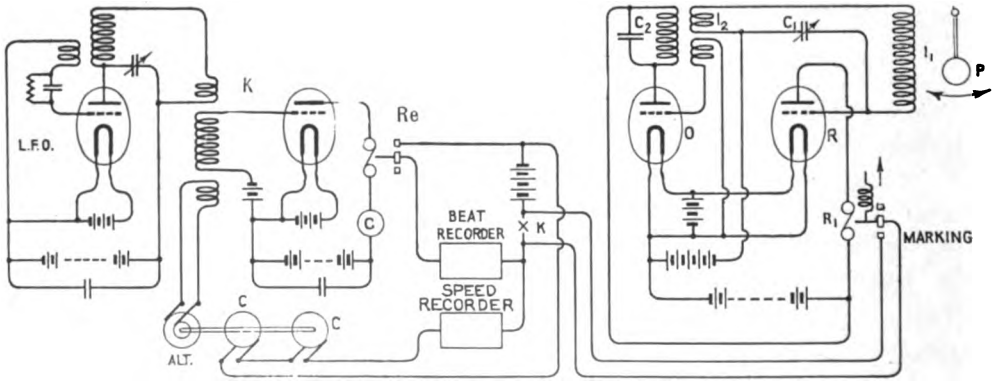

FIG. 7.

than the oscillator. Relay R_1, being in operation the beats can be recorded over a length of time on the slow beat recorder (Fig. 7).

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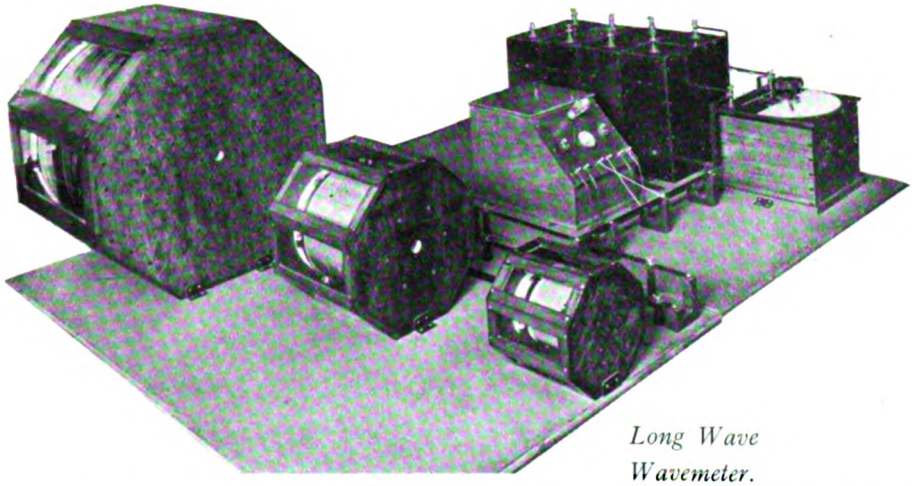
The oscillator Frequency is Machine Frequency plus Beat Frequency per sec.

The machine frequency is found in the following manner :



Long Wave Wavemeter.

On the shaft of the alternator are two commutators geared 10/1 (Fig. 8). The high speed one which is at shaft speed has 9/10 of its periphery insulated and 1/10 conducting. The low speed has 1/10 insulated and 9/10 conducting. Each is provided with 2 brushes which are connected as shown in Fig. 8. A phasing arrangement between the two commutators is fitted.

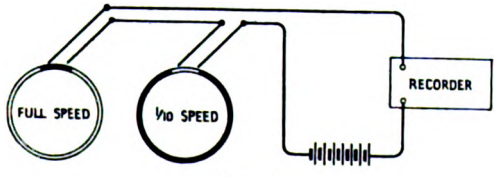


FIG. 8.

The machine has 60 pairs of poles, therefore R.P.M. are equal to cycles per second.

If the machine is run with the two commutators, a battery and a recorder in series, the recorder tape will be a series of dots with every tenth one missing as shown in Fig. 9.

This missing occurs when the insulated portion of the slow speed commutator passes under its pair of brushes when the conducting portion of the high speed commutator passes under its pair of brushes. This is a device for facilitating

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counting. Dots can be counted in tens and end ones added. The complete number so found, divided by time of run in minutes, is cycles per second.

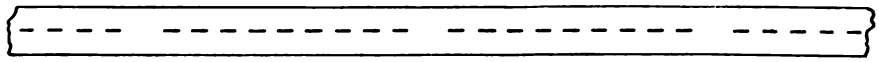

FIG. 9.

The timing of a run presented great difficulty. It was found that the eye was not automatic enough to enable accurate switching to be done. A device to improve timing was therefore built up. This consists of an oscillating valve and a detector valve. The filaments of these together with a resistance are in series across the station battery. H.T. is also supplied by the same battery. From the oscillator a single turn coupling is taken and connected in series with a small coil which is placed behind the pendulum of the standard clock, to be just overshadowed by the pendulum

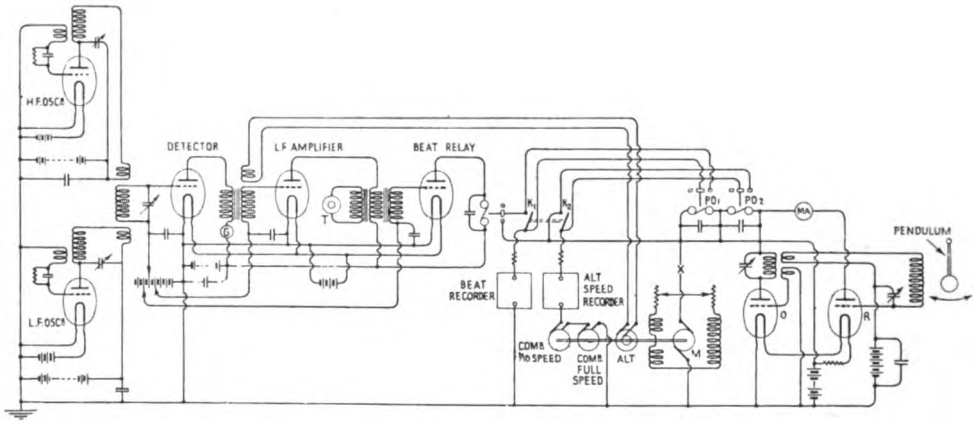

FIG. 10.

when it is at its full swing (Figs. 7 and 10). A tuning condenser is connected across the extremities of the coupling and choke coil which are as stated in series. The pendulum of the clock is of beech wood with a brass bob and makes one complete swing in two seconds. The tuned circuit is connected to grid and filament of the detector valve with suitable grid negative, and is so arranged that it is brought into tune with the oscillator when the pendulum is at full travel. Anode current then passes and relays PO_1 and PO_2 are operated for a short time (Fig. 10).

Across the contacts of PO_1 and PO_2 are connected the switches K_1 and K_2 respectively. These switches are operated by one handle and have micrometer contacts so that both close and open together. On account of the swing of the pendulum PO_1 and PO_2 are operated every two seconds, and if the alternator is running with circuits and recorders switches out, a record will appear on the tapes at 2 sec. intervals (Fig. 11).

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FIG. 11.

If now the switches K_1 and K_2 are closed the two second break is obliterated and the recorders show the continuous record of machine dots in groups of 10, and a record of the slow beats between alternator and L.F. oscillator.

Everything being adjusted as described the observer waits for the second hand of the clock to arrive at a marked place on the dial. At this point PO_1 and PO_2 close by means of the pendulum valve circuit and the switches are then closed by hand. A run of a suitable length of time is now made and as the second hand again approaches the marked point on the clock dial, after the proper period of time, the switches K_1 and K_2 are opened, immediately before the completion of the time, and on the actual completion of the time, the clock valve relay again operates closing the relays, PO_1, PO_2 and causing the recorders to operate.

This gives a tape as shown (Fig. 12) :—

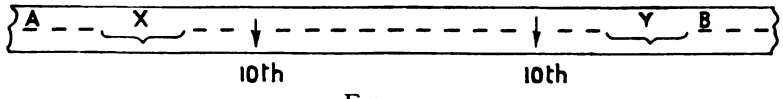

FIG. 12.

The actual run is from the first dot A to the dot B. It will be seen that at X and Y blanks occur. These correspond to the lag in closing and the lead in opening the switches K_1 and K_2 by hand, but as the tape record is divided in tens, and as the tape speed is constant over short intervals of time, these missing dots can be filled in without any fear of error.

The machine speed and beat frequency is now known from which is derived L.F. oscillator frequency.

Selection of Harmonics.

In the experiments both the high and low frequency oscillators have been calibrated. As the first wavelength measured was of the order of 10,000 cycles, the L and C values of the various circuits did not permit of a great error arising. The machine running at approximately 2,500 r.p.m. the H.F. was the fourth harmonic of the alternator frequency. This harmonic was multiplied by the L.F. which gave the H.F. value. From this steady progression to higher frequencies in small steps has been made many readings being taken on each point, and curves being drawn as the results were obtained, the harmonic increasing with the higher frequency. This method left no chance of error, for had the wrong harmonic been taken as the multiplier the curve would have shown a very sharp rise or fall not in accordance with the standard condenser calibration.

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Above 300,000 cycles it has been necessary to instal a higher frequency oscillator. The method is substantially as before, but in this case having set up the higher frequency oscillator, the medium frequency oscillator is started and tuned to zero beat, with the higher frequency oscillator, then the L.F. oscillator is started, and the adjustments are made as before, checking the medium frequency oscillator as in the case of lower frequencies.

Starting off from a known point which had been calibrated on the medium frequency wavemeter careful measurements in small steps were made to the higher frequencies.

The frequency meters described have a band of from 9,878 $\sim$ to 7,177,030 $\sim$ but it is often necessary to measure frequencies of a much higher order.

To do this the system is again extended and a very high frequency oscillator is set up and caused to interfere with, and then tuned to zero beat with an harmonic of the next lower frequency oscillator, after which the method is as described for measuring frequencies up to the limit of the calibrated instrument.

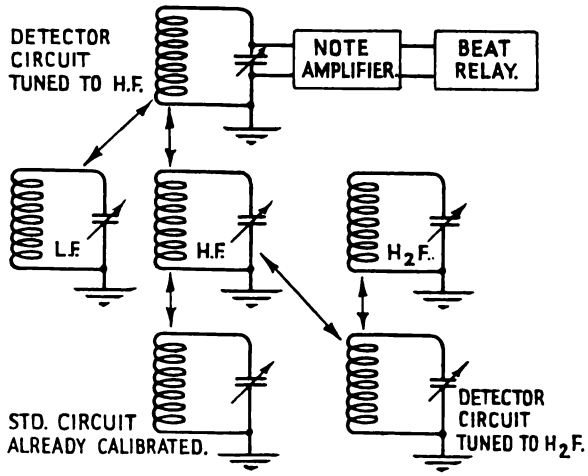

FIG. 13.

In conclusion the following remarks may be made.

The clock is of good quality, and is checked at least twice daily by means of time signals and a curve drawn. This gives a correction to be applied for each measurement made.

The scales of the instrument can be read to 0·1°.

In the case of a very definite measurement being required, *i.e.*, station jamming, the wavemeter reading is regarded as of secondary importance, and the station is measured by the fundamental method.

T. D. PARKIN.

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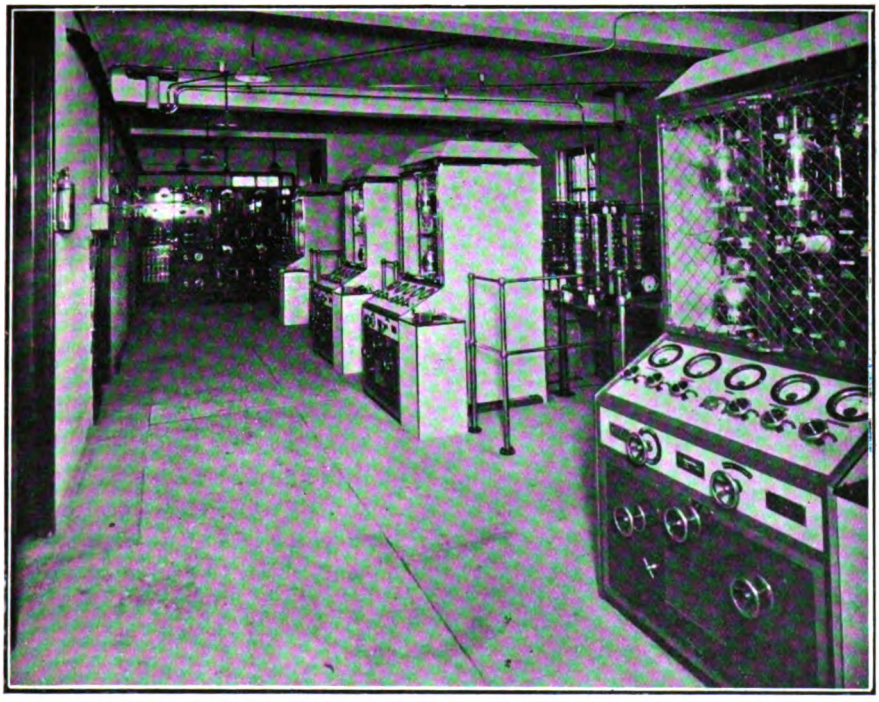
MARCONI NEWS AND NOTES

AIR ROUTE TO INDIA

THE WIRELESS ORGANISATION



London Air Port. Transmitter Hall with four transmitters designed and installed for the Air Ministry by Marconi's Wireless Telegraph Company, Ltd.

THE wireless organisation for the air mail service to India, which was inaugurated on March 30th, forms a complete chain so that the aircraft engaged are in touch with aerodrome ground stations throughout the 4,700 air miles of the journey from London to Karachi.

All the aircraft are equipped with Marconi wireless apparatus of the latest type, and an intercommunicating chain of ground stations has been arranged.

The first section of the route is the London-Basle flight, on which the present wireless organisation for Continental aviation will be employed. This consists of

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the powerful Marconi aerodrome station at Croydon, French stations at Le Bourget and other intermediate places on the route, and the Marconi station at Basle. The machines operating this section of the route—Armstrong Whitworth Argosies—are fitted with Marconi sets of 150 watts power, of the well known Type A.D.6, adapted for communication over distances of 200 to 300 miles either by telephony or telegraphy.

Marconi A.D. 6 Aircraft set fitted in Imperial Airways passenger machine.

From Basle the night train to Genoa makes the connection with the second section of the air route, from Genoa to Alexandria, which is to be operated by three "Calcutta" flying boats fitted with the more powerful Marconi Type A.D.8 sets. These sets are also adaptable for telegraphy or telephony, enabling the pilots to keep in touch with Italian and British Air Ministry wireless stations until arrival at Alexandria. In addition, Imperial Airways, who are conducting the London-Karachi service, have stationed a depot ship at a point in the Greek Archipelago. This has been fitted with a Marconi valve transmitter of ½ kw. power (Type U) and suitable receiving equipment (Marconi Type R.G.19 Receiver) and will be capable of communicating with Malta, Alexandria (Aboukir) and other stations concerned with the service.

At Alexandria a change is made to aeroplane again to continue the service over the third and final section of the route, through Basrah and over the Persian Gulf to Karachi. Part of this section has already been in operation for some time, employing De Havilland aircraft fitted with Marconi A.D.6 apparatus and communicating with R.A.F. stations and a ½ kw. station at Rutbah Wells, which was supplied by the Marconi Company to the Iraq Posts and Telegraphs Department. During the flight from Basrah to Karachi, the machines will be in touch with two Marconi stations in Persia, at Chabar and Bunda Abbas. Persian operators for these stations have been trained at the Marconi Company's Works at Chelmsford.

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A Powerful Aerodrome Station.

The terminal wireless station at Karachi is one of the most powerful aerodrome stations installed at any air port, consisting of a 6 kw. Marconi transmitter with direction finder receiving apparatus.

Many features of the Marconi apparatus for this service have been specially designed to meet the conditions existing on this new Empire route. The constant-speed windmill generator which provides power for the wireless installation will also supply current for the internal and external lighting of the aircraft. In the unlikely event of a forced landing being necessary the same generator can be used to supply emergency power to the transmitter either by the use of the battery normally used for lighting or, if it is required to work for long periods, by means of a special coupling arrangement to the small petrol engine used for starting the main engines of the aircraft. Thus, even if a machine were forced to land in the solitudes of the desert country which is to be found along the route, wireless communication could be established with the nearest ground station and any required assistance could be obtained.

The Air Ministry and Imperial Airways, Ltd., with the co-operation of the Marconi Company, have given very careful consideration to the wireless requirements of this first long distance Empire aviation route, and the comprehensive system of communications provided both for the ground stations and in the aeroplanes will render the England-India air route among the safest and most efficient in the world.

New High Power Broadcasting Transmitter for Sweden.

The Swedish Government has placed an order with the Marconi Company for the supply of a 60 kw. aerial energy transmitter for installation at Stockholm.

This contract was obtained by the Marconi Company in the face of the keenest competition, a success which is a tribute to the excellent design and performance of British broadcasting transmitters.

The new Swedish broadcasting station will be effective over a very large area. It will be operated on the low-power modulation system, with deep and distortionless modulation, and will be worked direct off a three-phase public electric power supply.

Marconi Broadcasting installations are now operating in over 20 countries outside Great Britain.

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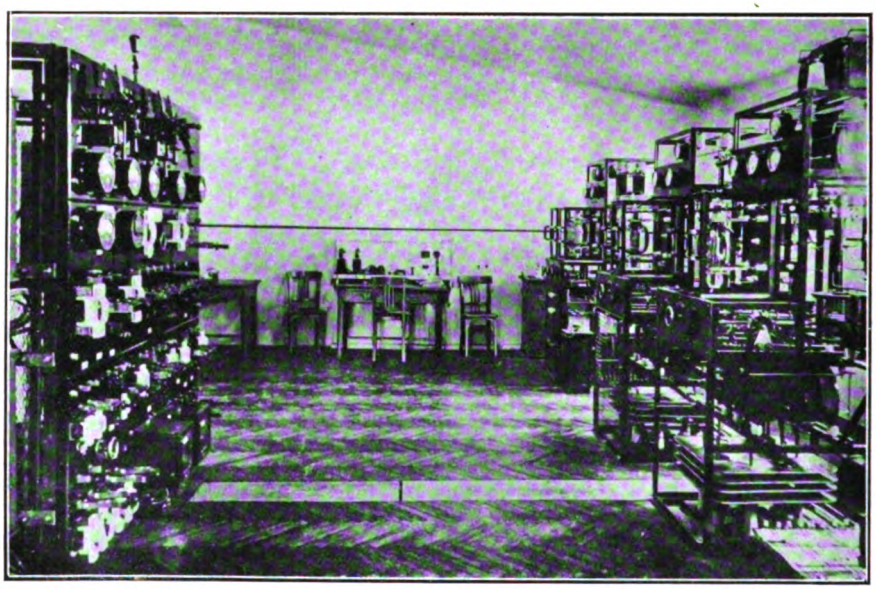
Marconi Broadcasting Transmitter in Yugo Slavia.



Marconi 9 kw. Broadcasting Transmitter at Belgrade.

A Marconi 9 kw. broadcasting transmitter has been installed at Belgrade for the Yugo Slavian broadcasting authority.

The official inauguration took place on Sunday, March 24th, in the presence of a representative of the King of the Serbs, Croats, and Slovenes, Members of the Cabinet and other high Government officials. The station was reported to be an unqualified success owing to the high efficiency of the transmitter. It gave very satisfactory performances during its tests, and a Swiss observer describing his reception of this station in *World Radio* says :—

> " Modulation is perfect and there is very little fading. I think I can safely promise that this newcomer to the Continental ether will be easily heard in England at good loudspeaker strength. Speaking from a mid-European point of view, Belgrade—which seems well clear of all the stations and is neither interfered with, nor itself causes any interference—is a very welcome addition, and I think we can now look forward to some enjoyable programmes from this historic city."

An English correspondent to " Radio Belgrade " reports that station " just as distinct as our own station in Liverpool, and clearer and louder than any other Continental station."

This 9 kw. installation, Type Q, is one of the smaller Marconi broadcasting stations delivering 2 kw. to the aerial. Before acceptance it had to pass extremely onerous reception test conditions.

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THE MARCONI REVIEW

May, 1929

CONTENTS

SHORT WAVE SIGNAL STRENGTH MEASURING APPARATUS—I	PAGE 1
A NAVAL DIRECTION FINDER—TYPE D.F.M.4	,, 7
BROADCAST POWER AMPLIFIERS	,, 12
A SHORT WAVE AIRCRAFT TRANSMITTER - TYPE A.D. 21	,, 21
THE TRANSMISSION UNIT	,, 24
MARCONI NOTES AND NEWS—	
NORSK MARCONIKOMPANI'S TENTH ANNIVERSARY	,, 27
BELGRADE WIRELESS STATION	,, 31
SHORT WAVE BROADCASTING TRANSMITTER FOR ITALY	,, 31
COMMUNICATION WITH BELGIAN COLONIES	,, 32

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THE MARCONI REVIEW

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Technical Editor: H. M. Dowsett, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. Rhards.

SHORT WAVE SIGNAL STRENGTH MEASURING APPARATUS

GENERAL CONSIDERATIONS

In the last number of THE MARCONI REVIEW *a brief history of the design of Signal Strength Measuring apparatus was given, and a reference was made to some of the difficulties encountered in such investigations.*

In the present article the factors which contribute to the success of a Signal Strength Measuring Set are discussed, especially from the point of view of short wave working. The question of the best type of aerial system to be employed is considered, as is the effect of the instrument itself on the field to be measured. Equalisation of signals by ear is shown to be, in general, unsatisfactory, and some form of recording device should therefore be used.

The calculation of the E.M.F. induced in a frame with a given input current is described, and the calibration of the instrument is explained.

A further article of this series will be published at a later date.

WITH the ever increasing use of short wave radio communications, the need for accurate measurements of signal intensity on this wave band has become acute.

A knowledge of the power necessary for any given service depends upon such measurements, and scientific investigations of signal transmission problems can only be advanced when such measurements are made.

The application of signal measurement to the short wave band presents special problems, not the least of which is the problem of what is actually to be measured. The simple method of determining the field strength induced in a vertical aerial is hardly sufficient, in view of our knowledge of the fact that the electric field in the wave is neither vertical nor simple.

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It has been suggested that this method avoids the effects of abnormal polarisation in the wave front, but our knowledge of short waves makes it appear that the so-called abnormal polarisations* are normal.

At any rate, these abnormally polarised* waves can be made use of in supplying energy to a receiver, and it seems, therefore, the wrong policy to neglect such conditions.

A frame aerial can be used to measure the components of the magnetic field both in the direction of the ray and perpendicular to the ray, and hence gives a more complete specification of the electro-magnetic field than the vertical aerial can.

It seems, therefore, preferable to use a frame aerial, by means of which both normally and abnormally polarised components can be measured, and the value of the frame is enhanced by the fact that it is much easier to calculate its effective area than it is to calculate the effective height of a vertical aerial.

It was this latter consideration which had most weight in deciding the form of aerial used.

An ideal measuring set should not modify by its presence the quantity to be measured.

Unfortunately, the presence of the shielding boxes containing the calibrating apparatus must in itself produce some modification of the field, but, if possible, this should be a minimum.

When the dimensions of the apparatus are small compared with the wave length, this acts in the first approximation as an equivalent oscillator at the centre of the box.

The secondary magnetic field from such an oscillator will consist of circular lines of force with their centres along the axis of the equivalent oscillator. If the frame is placed symmetrically on the box, there should be no coupling between this secondary field and the frame.

This can be seen more clearly from the figure (Fig. 1). With a vertical aerial it is impossible to avoid some coupling.

For such reasons a frame is used and coupled symmetrically on to a receiver as shown in Fig. 2.

In order to measure the signal E.M.F. induced in the frame aerial, the usual procedure of inducing a known E.M.F from an auxiliary source is employed.

The frame coupled to the receiver will give a response to incoming signals which can be equalised or matched by signals from the auxiliary oscillator.

* Polarised with the electric force in the horizontal plane.

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This process of equalisation adds another difficulty in the short wave case which is not present in the long wave case. This difficulty is occasioned by the rapid fading of signals which may vary in amplitude over a range of 8 or 10 to 1 in the course of a few seconds.

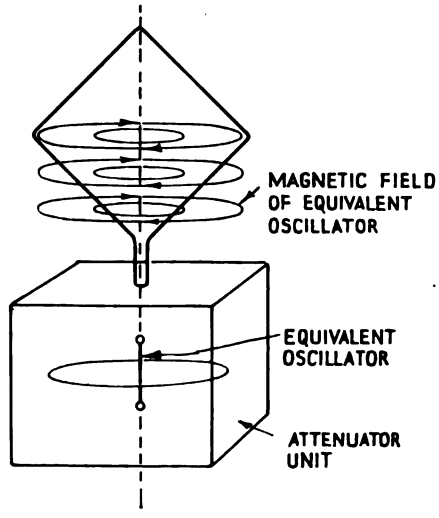

FIG. 1.

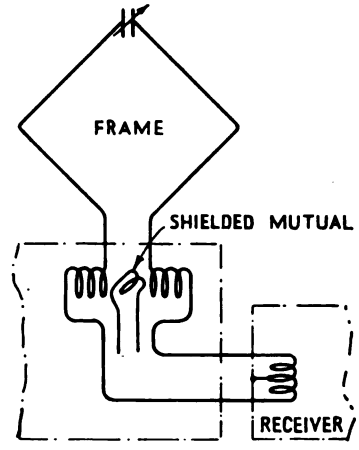

FIG. 2.

The only feasible method in such conditions is to record the signals and use the auxiliary oscillator to make calibrating marks on the record.

A receiver capable of recording the signals should therefore be used.

The attempt to match the received signals and the auxiliary signals by ear in a telephone is, in general, hopeless when the former is varying so greatly. This method can only be used on relatively local signals which do not vary. Some difficulty may be experienced in introducing the calibrating marks if the station measured is working continuously, but it seems preferable to wait for a pause in the sending rather than use a dummy frame circuit which may introduce one more degree of uncertainty.

In designing the set, an eye has been kept on continuity of design with the long wave measuring set, with the aim in view of making the same set function over the complete range of radio frequencies merely by interchanging the coils and frame belonging to it.

For this reason a certain amount of portability has been sacrificed to obtain universality and robustness in design.

In the original long wave set a mutual inductance was used to induce the auxiliary E.M.F. in the aerial, and this feature proved to be a very convenient

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method of continuously varying this E.M.F. A similar method was hoped to be practicable in the short wave range. This was found to be the case.

There are, however, difficulties in using a mutual alone, especially in the short wave range. The voltage induced in the frame is in many cases of long distance transmission, measured in microvolts, or even fractions of a microvolt, and it is impossible to design such a small measurable mutual inductance which will give these output voltages in the secondary with a measurable input current in the primary. Another difficulty is that the variable coupling of the mutual to the aerial reacts back on the auxiliary oscillator and changes its frequency, and absolute constancy of frequency is an essential in working, especially in the short wave band. A suitable attenuator placed between the oscillator and the frame avoids these difficulties, and the combination of the two offers very considerable advantages. The scheme therefore employed is shown in the accompanying diagram (Fig. 3).

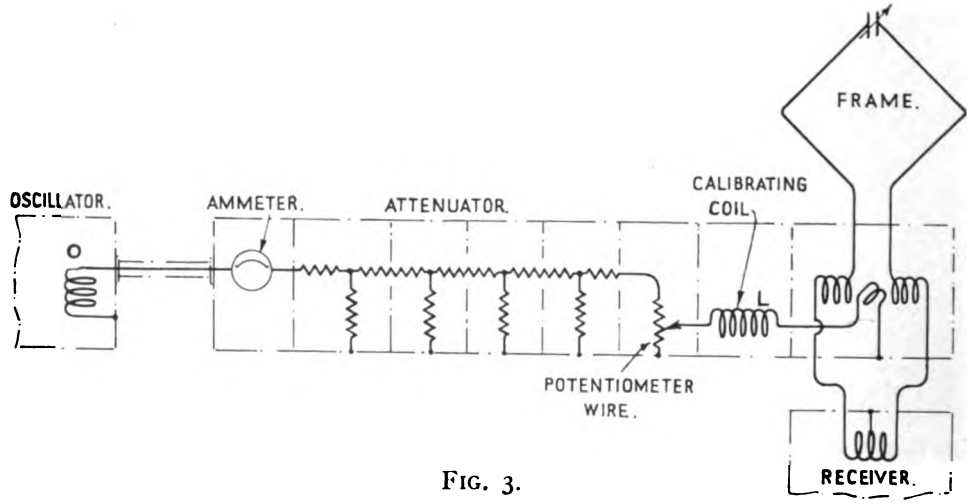

FIG. 3.

O is the auxiliary oscillator capable of supplying current at any desired frequency in the wave band (14 — 5,000).

This is coupled through an ammeter (measuring up to 125 M.A.) to a T form attenuator of about 7 ohms impedance, the output of which is passed through a potentiometer wire (7 ohms), across which is tapped the calibrating choke L and the primary of the mutual inductance, the secondary of which is part of the frame aerial, which in its turn is coupled to a suitable receiver.

The E.M.F. induced in the frame can be calculated as follows :—

Let I be the measured current in the ammeter (assumed to function correctly with sufficient accuracy up to the highest frequencies used). Then, if there are

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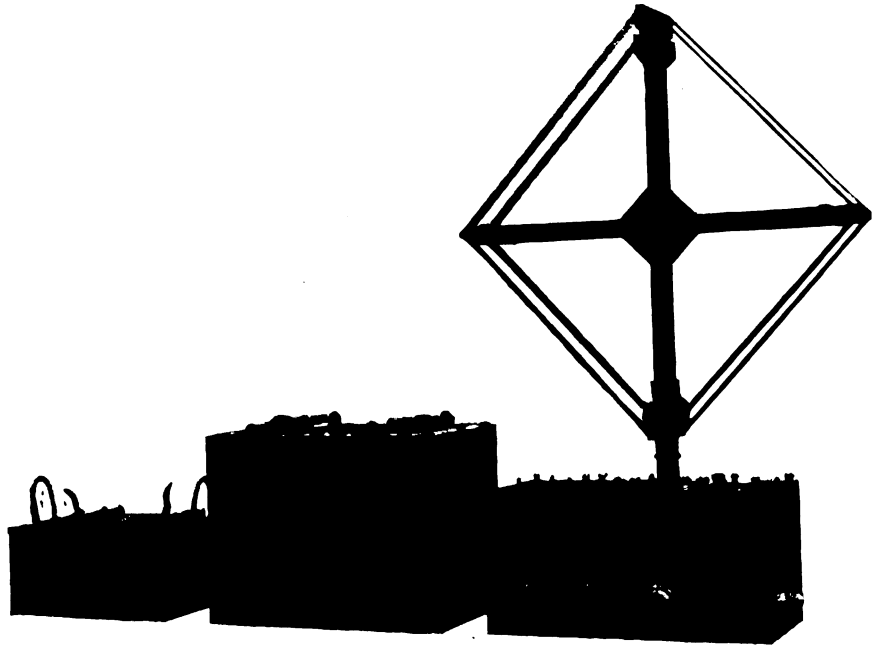
n sections in the attenuator, each with a reduction coefficient K, the output current in the potentiometer wire is K"I. If ρ is the resistance across which the primary of the mutual is tapped, then the E.M.F. in this circuit, including M, is ρ K"I, and the current is $i = \frac{\rho \text{ K"I}}{jLp}$ (resistance neglected), and the E.M.F. induced in the frame is $Mpi = \frac{M}{L} \rho$ K"I, and, except for slight corrections is independent of the frequency.



The performances of the attenuator and the mutual can be made to check each other, for if the auxiliary oscillator is arranged to give a definite output with a given arrangement of M and the attenuator, then the same output can be obtained by cutting out one section of the attenuator and decreasing the mutual inductance. If the latter has been calibrated, the change in its value will measure the change in attenuation of one unit in the attenuator—that is, the attenuator can be checked against the mutual, and as the former, in the ideal case, can be calculated, we can see whether the attenuator is behaving as it ideally should, and the self consistency of the calibration can be tested. This is a very important point, and there is always considerable doubt, especially on the short wave band, whether the performance is as specified, or whether small accidental capacities are producing spurious results.

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Special Design Difficulties on the Short Wave Band.

The difficulties experienced in working on very short wavelengths can be attributed almost entirely to accidental coupling capacities, and it will be realised that with frequencies as high as 2×10^7, the effect of a few centimetres coupling capacity is as great as that of a considerable condenser of 0·002 or so mfd. on the long wave band (15,000 M.). It is therefore essential to avoid such, and to obtain as nearly as possible perfect screening

(A) from the auxiliary oscillator, and

(B) between the parts of the attenuator.

To obtain perfect screening of the oscillator, this is put in a double box, and the controls are brought out through shielded holes. In the attenuator, the shielding of one unit from another requires careful design, which will be described more in detail in the next section.

T. L. ECKERSLEY.

Frame Aerial.
Type F.g.6.

SHIP TYPE FRAME AERIAL

TYPE F.g.6

The illustration shows the type of frame aerial which is used in conjunction with the type D.F.M.4 direction finder and is described in detail in the next article.

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A NAVAL DIRECTION FINDER

TYPE D.F.M.4

Wireless apparatus for naval use, is in general, subjected to rougher treatment than is the case with apparatus designed for ordinary use. When such instruments are erected on board warships, where the firing of guns, etc., introduces a considerable amount of vibration, the need for substantial design and shock absorbing devices is especially important. The Type D.F.M.4 Naval direction finder was designed with the above facts in view and combines selectivity and sensitivity with great mechanical strength.

The results obtained with this instrument have fully justified the care that was taken in its design, and have proved that such an instrument is capable of giving exceptionally good results, even when used under adverse conditions.

THE Type D.F.M.4 direction finder has been designed to receive both spark and continuous wave signals of from 350–4,000 metres. This is covered in three ranges, approximately as follows :—

Range 1. 350–750 metres.

Range 2. 750–1,800 metres.

Range 3. 1,800–4,000 metres.

As in the case of the R.G.19 receiver, the D.F.M.4 direction finder has been designed for use on board warships where space is of primary importance. It will be seen from the photograph of the instrument shown below that the receiver has been made in as compact a form as possible, compatible with mechanical strength and efficiency.

The complete receiver is enclosed in two brass boxes, one containing the radiogoniometer and strength control, and the other the complete amplifier and tuner. These boxes are supported by specially designed shock absorbers.

The instrument utilises the Marconi-Bellini-Tosi system of direction finding and employs two metal shielded loop aerials mounted at right angles to each other and supported on a metal pedestal. A small unshielded vertical aerial of suitable dimensions is also used for " sense " determination.

The advantage of the Marconi-Bellini-Tosi system over any rotating frame system is that the aerials can be separated from the receiver, and can be mounted in any convenient position, both as regards pick-up and segregation from metallic masses, etc. When rotating frame aerials are used, as these act as the radiogoniometer of the direction finder, they must be mounted directly over the receiver.

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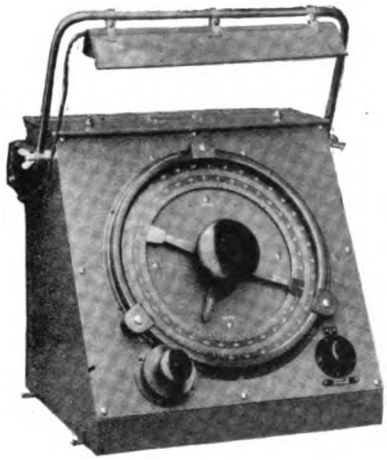
Under favourable circumstances, *i.e.*, where no masses of metal are in close proximity to the frame, no aerial correction chart is needed in conjunction with fixed aerial systems, whereas any rotating frame system necessitates the use of such a chart.



D.F.M.4 Radiogoniometer.

The Marconi-Bellini-Tosi system enables a high degree of accuracy to be obtained on all bearings taken within the extreme navigational range.

A simplified diagram of connections of the radiogoniometer and receiver is shown in Figs. 1 and 2 and a detailed description of the various components is given below.

Aerial System.

The shielded frame aerial system intended for use in conjunction with the D.F.M.4 is illustrated in the photograph on page 6. It consists, as will be evident, of two circular loops, one mounted inside the other and at right angles to it. The two are supported at a convenient height on a pedestal.

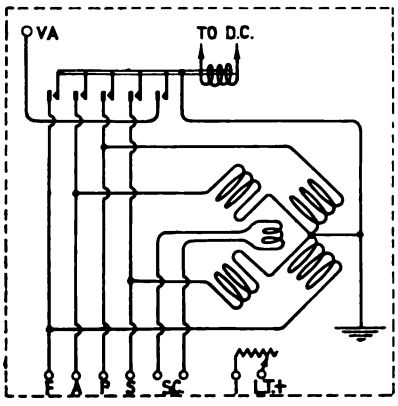


FIG. 1.

The two loops are of slightly different size, the smaller loop being placed accurately along the centre line of the vessel. The diameter of the larger loop is 4 ft. 5 in. The whole system is arranged so that it can be taken to pieces easily, the two loops being detachable from the pedestal.

Each loop is supported inside a copper tube. These tubes are bonded together at their mid-point and are connected to earth through the pedestal by means of a metal rod. Their extremities are carefully insulated from the pedestal by means of an insulated packing; this insulation being extremely important for the correct functioning of the complete system. Each loop consists of four turns of rubber-covered wire carefully insulated from the screening tubes.

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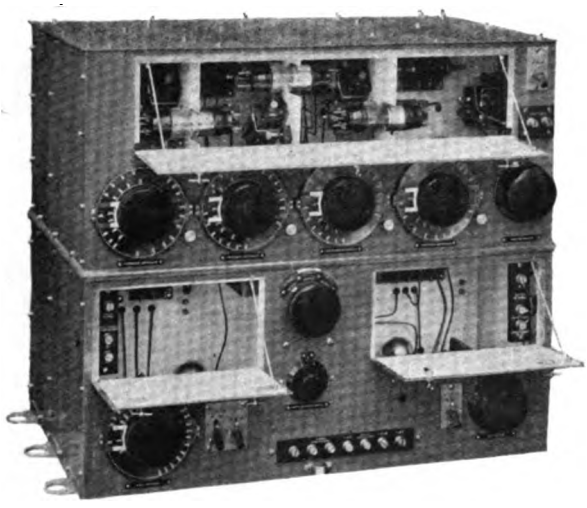
The pedestal is of brass and is obtainable in various heights to suit different requirements. The leads from the two loops are connected to dry core lead-covered paper cables via suitable junction boxes and are passed through the pedestal in a convenient way and thence to a junction box located close to the radiogoniometer. Leads are taken from this junction box to the radiogoniometer terminals.



D.F.M.4 Receiver.

These frame aerials together with the vertical aerial system to be described later, enable either a figure-of-eight or cardioid polar diagram to be obtained.

Radiogoniometer.

The radiogoniometer consists of two similar field coils, fixed in position, and crossing each other at right angles. The four ends of these coils are connected to the corresponding ends of the loop aerials, as described above. The coils are mounted on a hollow cylindrical former and are well insulated from each other. A rotatable search coil is mounted symmetrically inside the former in such a manner that it can be set at any angle relative to the two field coils, and its direction read off accurately on a scale provided at the front of the receiver.

The whole radiogoniometer is mounted in a brass box with a sloping front to enable readings to be taken with greater ease and accuracy. A volume control is mounted in the radiogoniometer box, and a light is provided for illumination of the scales. These scales consist of one fixed and one rotatable 360° scale to enable either relative or true bearings to be obtained. This device has been found to be of great use in automatically eliminating a certain amount of calculation, and if operated by a gyro repeater compass greatly simplifies the operation of the direction finder.

The Receiver.

The receiver employs three stages of transformer coupled high frequency amplifiers, an anode bend detector, and a resistance capacity coupled note magnifier. A local oscillator is provided for the reception of the continuous wave signals.

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It will be seen from Fig. 2 that the search coil of the radiogoniometer is connected to a closed tuned circuit provided with two coupling coils, one to the vertical aerial coupling valve, and one to the tuned grid circuit of the first high frequency valve.

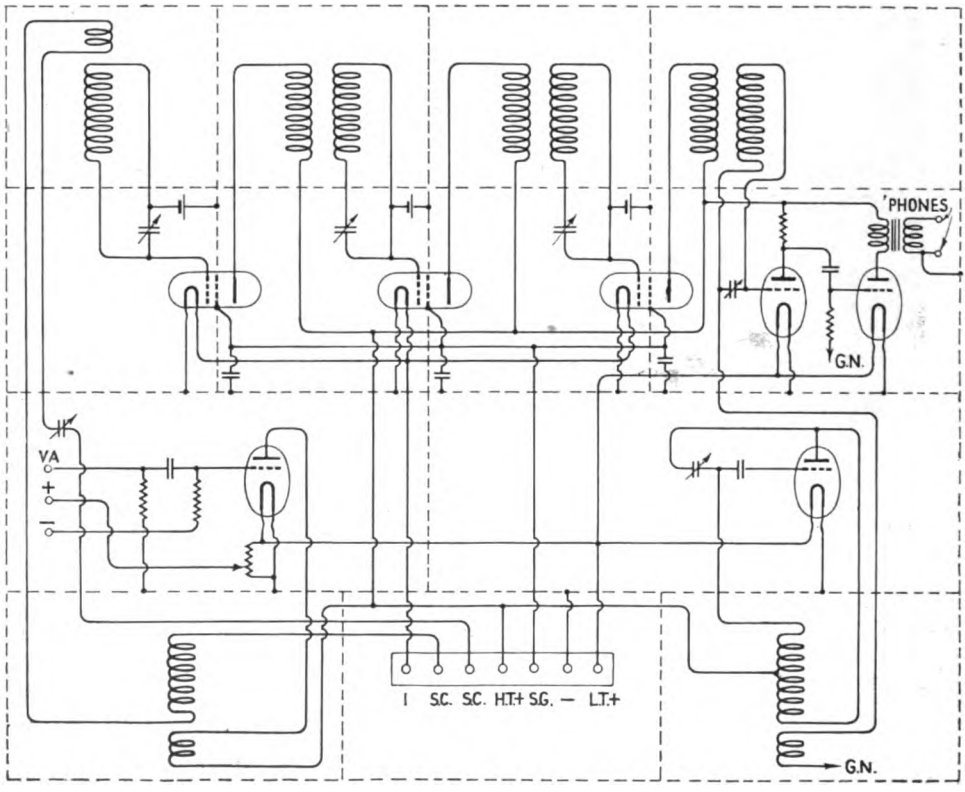

FIG. 2.

The aerial used for sense determination is coupled to the search coil circuit by means of a coupling valve. The signals are applied to the grid of this valve by means of a suitable resistance capacity arrangement. The use of such a coupling valve enables a smaller aerial to be employed, and at the same time, sufficiently good sense indications to be obtained over a large range of wavelengths without adjustment. This fact is of especial importance on warships where the use of a large aerial may be very inconvenient.

The intensity of vertical aerial signal is variable by means of adjustable grid negative on the coupling valve. This enables the correct amplitude of vertical

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aerial signal to be combined with the signal from the loop aerials to produce a fine cardioid diagram of reception and thus to obtain good sense indication.

The three high frequency screened grid valves are transformer coupled with tuned grid windings. The coils are astatically mounted, and the set of coils for each stage is enclosed in a separate shielded compartment of the main receiver box. The tuning condensers for the grid windings are operated individually but are provided with a gang control to enable a small band of about 10 per cent. either side of a desired wave to be searched quickly. This device facilitates tuning, as each condenser may be accurately tuned to some pre-determined wave and the final adjustment to the desired wave made by the gang control. The condensers are fitted with special scales to enable the actual wavelength in metres to be read on any of the three ranges.

The coils for the high frequency transformers are changed by means of ganged barrel switches operated from the front of the receiver by a bevel gear and shaft.

After passing through the high frequency amplifiers, the resultant signal is rectified by an anode bend detector. In the grid circuit of this valve is a coil coupling into the output of the local oscillator. The local oscillator is of the usual type and needs no special description. The connections of it can be clearly seen on reference to the diagram. Switches are provided enabling the valve normally used for this local oscillator to be employed as an extra stage of note magnification if desired.

The rectified signal is amplified still further by a resistance-capacity coupled amplifier connected in the usual way.

The receiver is designed to work with low resistance telephones, and a step-down transformer is provided with the high resistance winding in the anode circuit of the last valve.

Stability.

The question of stability has been very carefully considered in the D.F.M.4. In the case of receivers employing a large amount of high frequency magnification, it is found in general that a compromise has to be effected between high electrical efficiency of each high-frequency stage, and overall stability of the receiver.

In the case of the D.F.M.4 the combination of three stages of high-frequency magnification with small astatic coils has been found to give extreme stability and remarkably constant voltage magnification over a large range of wavelengths,

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BROADCAST POWER AMPLIFIERS

The following article deals briefly with the design of the "power amplifier" type of transmitter, and with the reasons which made such design advisable as an alternative to the full power modulation method.

The question of adjustment and efficiency of a power amplifier is discussed, and a typical set of this class, the Type P.A.5 broadcast transmitter, which was described in the November number of THE MARCONI REVIEW, *is examined in detail.*

Harmonic radiation from valve transmitters is, undoubtedly, responsible for much interference at the present time, and means to avoid this are mentioned in the last part of the article.

IT will be desirable to commence by defining what we mean by a "power amplifier." Obviously, any transmitter with a driving stage includes a power amplifier, but the particular type we propose to discuss is one so adjusted as to be capable of amplifying linearly a modulated high frequency input applied to its grid. To do this the amplifier must be adjusted in a particular manner. Referring to Fig. 1, it will be seen that the left-hand diagram shows the static characteristic of a valve, and underneath a representation of an alternating voltage applied to the grid, varying above and below the point Gb., which represents the fixed negative grid bias.

The dotted curve marked "B" represents the voltage swing that would be applied to the grid if the amplifier was intended for C.W. morse transmission. It is assumed here that an increased grid swing would not increase the output, the point "B" being that at which a limit is reached either of filament emission or anode voltage. It is obvious therefore that with such a carrier setting no linear modulation is possible. Again, in the middle diagram of the same figure is shown the alternating anode volts varying about the line V_0, which is the supply voltage, the dotted curve "B" representing the conditions appertaining to a telegraph transmitter. It will be observed that the anode volts swing upwards to nearly $2V_0$, and down to nearly, but not quite, zero.

It is important that the anode voltage should not swing lower than about one thousand volts above zero, as if it does, remembering that the instant of minimum anode volts is that of maximum positive grid volts, the grid may become positive to the anode with undesirable effects due to secondary emission. It will be appreciated, therefore, that with such a plate voltage excursion as above described modulation is also impossible. To produce a condition capable of modulation, the grid input to the power amplifier must be of less amplitude than curve "B," and the anode swing likewise less than curve "B" of the middle diagram. The curves

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"A" on these diagrams show an adjustment which will permit of 100 per cent. modulation without infringing the conditions laid down. This matter of the carrier adjustment of the amplifier, to make it suitable for a permissible degree of modulation, raises the question of efficiency. By the efficiency of a valve we mean the ratio of alternating power output to unidirectional power input. The efficiency of the valve is practically directly proportional to the alternating anode volts. The input power, of course, is the product of the supply voltage and the anode direct current. The output power is the product of the R.M.S. values of the alternating anode volts and the alternating anode current, and this latter is the direct anode current multiplied by a certain form factor, which depends upon the value of the grid bias.

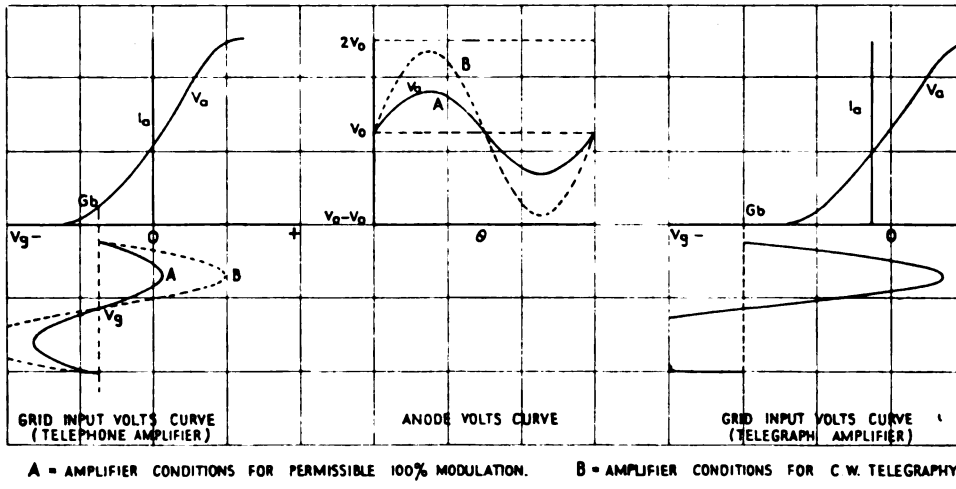

FIG. 1.

Under the working conditions of the particular type of amplifier we are considering, this form factor approximates 3·2, that is the peak value of the alternating anode current is about 3·2 times the anode current as read on a D.C. instrument. In the case of an amplifier adjusted as represented by the right-hand diagram of Fig. 1, the form factor may amount to as much as 5 or 6, and the efficiency is increased by such an adjustment of the grid bias. An amplifier of this type, however, is only suitable for C.W. transmission and anode voltage modulation, or possibly as a power amplifier for tonic train signalling, as the anode variations are no longer directly proportional to the grid input. Consideration will show that in such an amplifier the anode output may be completely modulated by a comparatively weakly modulated grid input, resulting in an amount of distortion quite undesirable in high quality telephony for broadcasting purposes.

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Efficiency.

This question of the efficiency of a power amplifier adjusted for modulation is not so well understood by many as it might be. It has even been urged as an argument against the full power anode voltage system of modulation, the so-called "choke-control," that the separate modulating valves used result in a waste of power, and that the system is therefore less efficient than the low power modulation method, where no high power modulators are necessary, or than the method employing a small valve as a variable resistance in the grid of an amplifier. Actually the overall efficiency, and the total number of valves necessary for a given output, is, for all practical purposes, the same in any of the three systems.

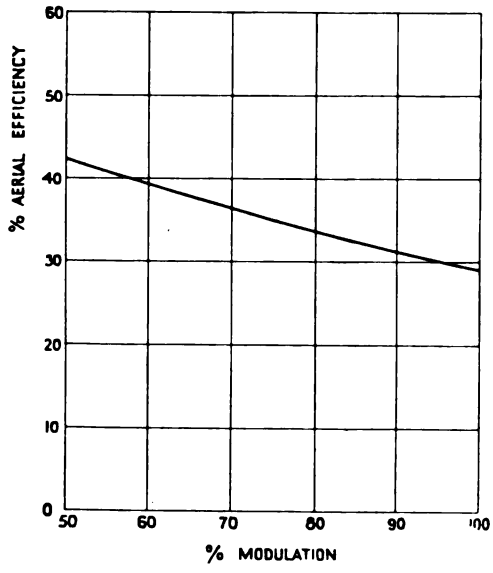

FIG. 2.

This point of efficiency being of some importance, it may be worth while to illustrate by a practical numerical example.

Let the amplifier valve be worked with a supply voltage of ten thousand and with a feed current of one ampere, that is, with an input of ten kilowatts. Assuming a required permissible carrier modulation of 100 per cent., and bearing in mind the lower limitation of anode swing to 1,000 volts above zero, it will be seen that the setting of the amplifier must be such that in the carrier condition the anode peak volts will not exceed 4,500. The peak value of anode current will be approximately 3·2 amps., and the alternating power is given by $\frac{4{,}500 \times 3{\cdot}2 \times {\cdot}7^2}{2}$ (two coming in as divisor because only half the grid swing is being utilised), or closely enough by $\frac{4{,}500 \times 3{\cdot}2}{4}$ = 3·6 kw., that is, a conversion efficiency of 36 per cent. If no modulation had to be allowed for, the anode peak volts could be adjusted to 9,000, and obviously both the output and the efficiency would be double the above values. Incidentally it follows from this that the number of valves required in a choke controlled amplifier is exactly half that necessary in a power amplifier for equal output, and assuming the valves worked to the limit of their permissible anode loss. Actually the proportion is even less,

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as in the former case there is no reason against using a large negative bias and operating the valves on the " flick " or shock excitation method with an efficiency greater than twice that of the power amplifier in its carrier condition.

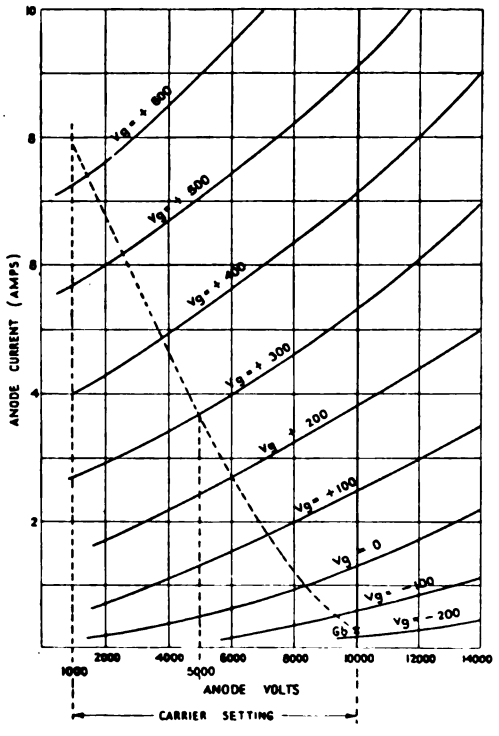

FIG. 3.

Fig. 2 is an approximate efficiency curve for a particular transmitter of the P.A. type, in which the efficiency of the amplifier, referred to aerial energy, is plotted against the adjustments for any required degree of modulation from 100 per cent. to 50 per cent. It will be seen that these values lie between about 28 per cent. and 42 per cent. respectively.

Fig. 3 shows the characteristic of a particular type of cooled anode valve manufactured by the Marconi-Osram Valve Company, and known as Type C.A.T.6, with adjustments suitable for a modulation of 80 per cent., these values, of course, referring to the positive swing of the input grid volts. It is assumed the valve is being operated at 10,000 volts with an input of 12 kw., a normal rating for such a valve. The fixed grid bias marked " Gb." is about 150 volts, giving a standing feed of approximately one quarter the anode current in the carrier condition. The driving input would be such that the anode peak volts reach 5,000 volts, a value capable of being varied 4,000 volts each way without running into bad operating conditions. Note the alternating power here is $5{,}000 \times 3{\cdot}84 \times {\cdot}25 = 4{\cdot}8$ kw., the conversion efficiency $\frac{4{\cdot}8}{12} \times 100 = 40$ per cent., and the power to be dissipated in the valve is $12 - 4{\cdot}8 = 7{\cdot}2$ kw.

Peak Voltmeter.

For studying these amplifiers and observing the working conditions, a most useful piece of apparatus is an instrument capable of indicating maximum alternating

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potentials between any two points in a circuit. Such a peak voltmeter is illustrated in Fig. 4. The instrument consists of a rectifier valve in series with a condenser, and shunted by a high resistance and a D.C. meter, which can be calibrated in volts. We use normally a valve of Type M.R.4 and a shunt resistance of one megohm. For anode voltage measurements, the meter is one giving full scale deflection with ten milliamperes and calibrated to read one thousand volts per milliampere. For grid voltage readings an instrument giving full scale deflection with two milliamperes and calibrated from 0 to 2,000 volts is convenient.

Reasons for adoption of Power Amplifier System.

It may be of interest to explain the reasons that influenced the Marconi Company in developing the power amplifier method for broadcasting transmitters, when for a number of years we had been using the full power modulation system with considerable success. As is well known, the modulation methods applied to broadcasting at the present time comprise three main types :—

(A) Full power modulation, generally known as the choke control system ;

(B) Low power modulation, or the power amplifier system ; and

(C) Grid resistance modulation, usually referred to as the Telefunken system.

This latter is really a power amplifier system, as the valve to which the variable grid resistance is applied has to be adjusted so as to be capable of responding to an increment in efficiency, and for a given permissible modulation the efficiency of this valve is approximately the same as a power amplifier.

Actually, in the high power German stations the modulation is carried out on an intermediate stage, and an extra power amplifier is added. We can say, therefore, there are only two distinct methods in use, viz., full power modulation and low power modulation.

The power amplifier method has been perfectly well known to us for many years. Captain H. J. Round took out a patent before the War, in which he showed an oscillating valve with modulation applied to it by driving an amplifier to increase the power to the aerial. The method is really hardly suitable for use with air-cooled valves, and in the early days of experimental broadcasting in this country, which commenced some time before water-cooled valves were available, we preferred other arrangements. At the first high power station at Chelmsford, which commenced working in 1920, and had an input of about 20 kilowatts, we used absorption control, and in smaller sets choke control, which we eventually standardised. A number of these transmitters were sold to the British Broadcasting Corporation and to broadcasting organisations in all parts of the world, and they are still providing

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very satisfactory service. Daventry (5XX), one of the most successful high power stations in Europe, was constructed on this system, as also was Motala, Sweden, a station with an aerial rating of 30 kilowatts. Apparently the first power amplifier transmitters to be used commercially were manufactured by the Western Electric Company of America. A number of small transmitters of this type, of about 500 watts output, were put into service in the United States, and a few were sold in Europe. These transmitters had a modulated master oscillator and one stage of power amplification, a not altogether desirable arrangement, but in later designs the modulation has been impressed on an intermediate amplifier, leaving the drive entirely independent.

A peculiar contention, which has apparently impressed many prospective customers, is the point that a power amplifier transmitter lends itself readily to any future increase of power by the addition of another amplifying stage, although why it is not appreciated that a similar addition can equally well be made to a choke controlled full power modulation transmitter is not at all clear.

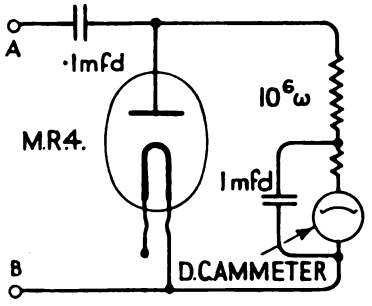

FIG. 4.

The B.B.C., however, made use of the power amplifier at their Daventry Experimental Station, 5GB, where they have obtained very successful results, and as this had considerable influence with other broadcasting organisations, and several clients requested tenders for stations of this type, with the intimation that specifications for full power modulation transmitters would not be acceptable, the Marconi Company decided to standardise a series of power amplifier sets.

Comparison of the two methods.

It has been frequently asked: "What are the comparative advantages and disadvantages of the two methods, particularly in connection with high power transmitters"? The only definite practical advantage the full power modulation method possesses is that the main valves are efficiently driven during the whole time they are in operation, and appear to be less liable to internal discharges under these conditions, while, should such occur, the short circuit current flow is limited

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by the high impedance of the modulation chokes. However, improvements in valve construction appear to be reducing the tendency to these discharges. A theoretical advantage to the credit of the full power system is that it is only necessary to make use of two tuned circuits carrying modulated high frequency currents, that is the main oscillatory circuit and the aerial itself, whereas in the other method several stages of amplification are usual after modulation, and consequently some care in design and adjustment is essential to avoid attenuation of the higher audio frequencies.

Some advantages of the power amplifier are that it is certainly easier to secure a level frequency characteristic when modulation is carried out on low power and with small valves and components, and the possibility of very deep modulation is more economically arranged for. In addition, no high power modulating valves are required, and the complications of maintaining these in satisfactory parallel operation consequently avoided. The overall efficiency of both methods is practically identical, any slight advantage, if existent, being in favour of the power amplifier. As to constructional costs for an equal power output, it appears this will be in excess for the full power modulated transmitter by approximately the expense of the modulation choke or transformer, which in large sets may be an appreciable item.

Type P.A.5 Power Amplifier.

The Type P.A.5 is typical of this class of transmitter, and has been described in the second number of MARCONI REVIEW. It is rated to give between 10 and 14 kilowatts to the aerial, depending on the degree of modulation required, at any wavelength between 200 and 545 metres.

In designing these sets certain features were agreed upon as essential in a transmitter at the present time. One of these desiderata was the provision of a carrier frequency unaffected by variations in the mains supply, or by modulation or other variations in subsequent stages of the set. The possibility of complete modulation was thought desirable, and, of course, as level a frequency characteristic over the useful audio range as could be obtained with a reasonable commercial efficiency. The reduction of harmonic radiation to a minimum was also considered to be of prime importance.

Commenting on the circuits stage by stage, starting with the Drive, it should be noted that the anode voltage for this stage is taken from a motor generator run off the accumulator battery which supplies the filaments. This arrangement ensures that the driving frequency is independent of fluctuations in the supply mains, and enables a very high degree of constancy to be maintained. The drive is coupled to the Isolator, which comprises a valve working without grid current in a neutralised circuit, with the result that the load on the drive remains constant, and any possible reaction back due to modulation is prevented.

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Next comes the Modulated Amplifier, on which is imposed the modulation potentials through the agency of an iron cored choke coil and the modulator valve. A three thousand volt supply is used for the modulator, and the same source feeds the modulated amplifier, but is dropped to about thirteen hundred volts for this purpose by means of a series resistance. Under these conditions the modulating apparatus is capable of producing full modulation of the amplifier output.

The modulated high frequency currents are induced on to the Intermediate Amplifier, which consists of a single water-cooled valve, worked with a negative bias of twelve to thirteen hundred volts. The characteristic of this valve is such that the required output is secured without running into grid current. The load on the modulated amplifier is consequently small.

The final stage is the Power Amplifier, which in this particular set comprises three water-cooled valves working with an anode input of 36 kilowatts, and giving about 12 kilowatts carrier energy in the aerial when adjusted for 80 per cent. modulation. A slightly modified set uses four of these valves in the final stage, with an aerial rating of approximately 16 kilowatts.

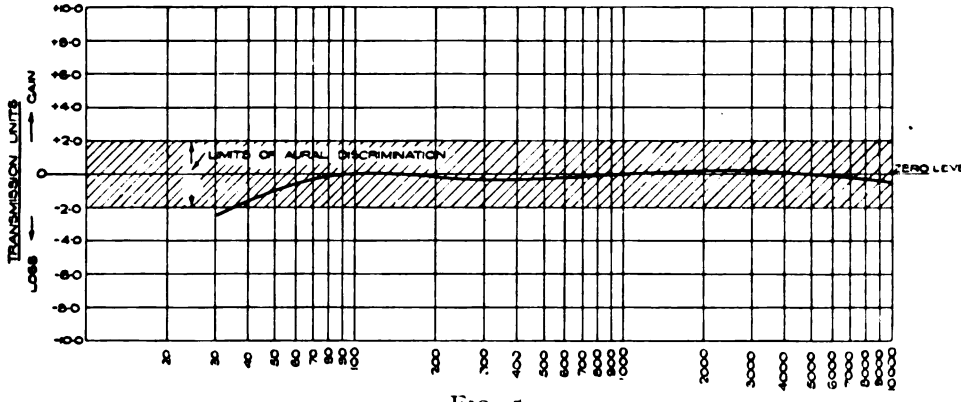

FIG. 5.

A frequency characteristic of this set is given in Fig. 5. It will be observed that this curve from 40 to 10,000 cycles is within 2 T.U. of the zero line, or alternatively, does not vary more than plus or minus 1 T.U. about a mean value. This degree of linearity means that over the frequency band mentioned the ear will be unable to detect any difference in amplitude, and consequently the curve can be considered flat over this range.

Elimination of Harmonics.

As previously mentioned, consideration has been given to the question of harmonic elimination. There is no doubt that the prevention of harmonic radiation

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from valve transmitters is a point of prime importance under present day conditions. Unfortunately, there appears to be no way of preventing harmonics being generated, and at the same time maintain a sufficiently high efficiency. We have, therefore, to devise means for preventing the undesired frequencies from reaching the aerial. This, again, is not a complete solution of the problem unless means are also provided for preventing radiation from the circuits and connecting leads inside the transmitter building. We have considerably reduced the trouble by placing all the tuning circuits in shielding cases, and still further improved matters by inserting a multi-

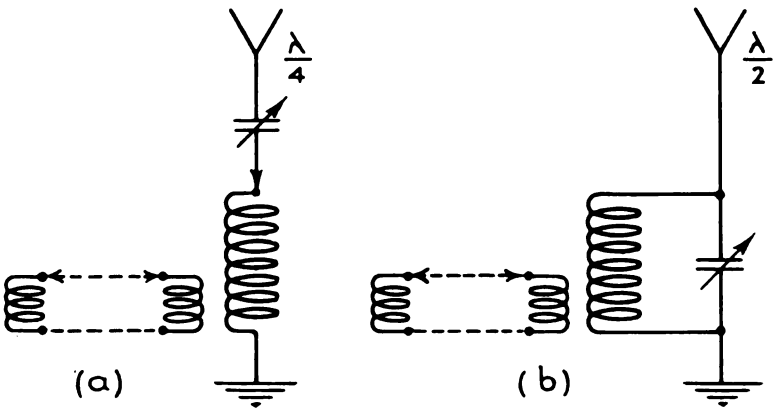

FIG. 6.

stage low pass filter between the oscillatory circuit of the power amplifier stage and the aerial. The harmonic filter is intended to work into a feeder line running to a remote building which houses the aerial tuning circuit. In Fig. 6 is a diagram of the arrangements used for the aerial coupling. It will be observed that the connections can be arranged to make the components suitable for use with either a quarter wave or a half wave aerial, or for any intermediate length.

An alternative arrangement is to connect the feeder across a coupling condenser in series with the aerial. This method tends to reduce harmonic radiation considerably, but does not completely solve the difficulty.

The harmonic filter arrangement is probably the best method at present available in combination with complete shielding of the transmitter. This, unfortunately, means increased cost, but is probably unavoidable, if the maximum freedom from undesired radiation is aimed at.

W. T. DITCHAM.

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A SHORT WAVE AIRCRAFT TRANSMITTER

TYPE A.D.21

For nearly 20 years the Marconi Company has paid special attention to the question of developing wireless apparatus suitable for use on all types of aircraft. This type of communication presents certain special problems, however, and it has long been known that the use of short waves was beneficial in solving some of the difficulties which arose in this connection.

In order, therefore, to make full use of these qualities, the Marconi Company have recently designed a series of improved short wave sets, specially adapted to the above purpose.

Reference has been made, in the December number of THE MARCONI REVIEW, *to some exceptionally good results obtained with experimental short wave wireless apparatus fitted to an air-liner on the Croydon-Cairo route, and this, with other reports of a similar nature, serves to show the great use that can be made of this type of transmission and reception.*

In this article an account is given of the A.D.21 transmitter which is intended for use in conjunction with the A.D.20 receiver which will be described later.

THE Type A.D.21 transmitter is designed to work on wavelengths of from 40–60 metres and to transmit on either C.W. or I.C.W. A photograph of the transmitter is given below. It will be seen that the complete set is mounted in a wooden box with a paxolin panel. The cover is not shown. The transmitting valve—a D.E.T.1.M/8, mounted in an R.A.F. type holder—is seen in the centre. On the left are mounted the send/receive switch, the variometer, and the feed milliammeter. On the right are the tuning condenser, I.C.W./C.W. switch, and the aerial ammeter.

A 6-point plug and power lead connect the generator to the transmitter, and suitable leads connect the transmitter to the A.D.20 receiver.

The complete diagram of connections of the transmitter is shown below (Fig. 1). Fuses are provided in the positive low tension supply and in the generator field supply which is closed by the send/receive switch through a 1-ohm variable resistance. A fuse is also provided in the positive high tension supply.

The send/receive switch, in the transmit position, completes the transmitter aerial circuit, connects the filament of the valve to the low tension supply and makes the field circuit of the generator. In the receive position the receiver aerial is connected up, and the receiver valves lit. It is essential, in this connection, to note that the transmitter aerial must always be connected just before the power is put on to the transmitter to ensure that the normal load is on the valve before the latter begins to oscillate. Ordinarily, whilst transmitting, the low tension battery is floated from the low tension supply of the generator.

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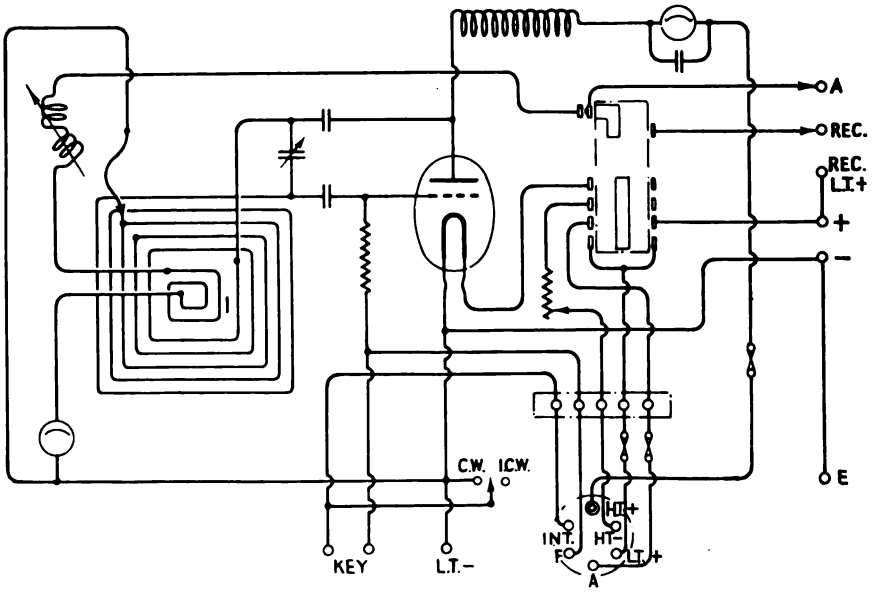
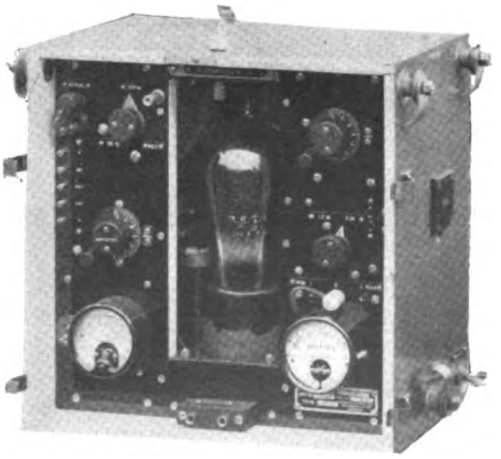


FIG. 1.

The oscillatory circuit is of a simple type and a simplified diagram of its connections is given below (Fig. 2).



A.D.21 Transmitter. Front View.

The closed circuit inductance consists of a helical copper strip of 9 turns rigidly supported by ebonite holders on a paxolin panel and mounted at the back of the set. This is connected across the grid and anode of the valve through two condensers, one in the anode lead, and one in the grid lead. The anode condenser is of ·001 mfd. capacity, and the grid condenser of ·003 mfd. capacity. The closed circuit inductance is tuned to the required wavelength by means of a ·0007 mfd. variable air dielectric condenser operated from the front of the set. A tapping on the closed circuit inductance is connected to earth.

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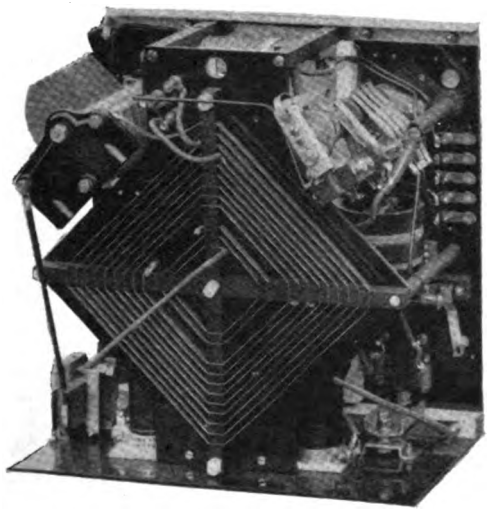
The aerial inductance is wound inside the closed circuit inductance, and consists of two turns of copper strip. One end of this goes through a variometer to the aerial, and one end to earth through an aerial ammeter.



A.D.21 Transmitter. Back View.

The high tension supply of 1,000 volts at approximately 60 milliamperes reaches the anode of the oscillator by means of a high frequency choke wound on a glass rod and passes through a feed milliammeter which is shunted with a ·001 mfd. mica condenser to by-pass high frequency currents.

Keying.

A 2-way switch is provided for changing over from C.W. to I.C.W. signalling. When on C.W. the rotary interrupter is shorted to earth. In this position the grid circuit of the valve is keyed through the grid leak. When the key is up, the grid, which is normally connected through the grid leak to negative low tension and negative high tension, is disconnected from negative low tension. In this way the positive potential of the anode with respect to the filament is removed with the result that no anode feed current passes. In other short wave transmitting sets it has been found that the normal arrangement whereby the grid circuit is broken, while the anode is still kept at its high potential with respect to the filament, permits a feed current to pass through the valve even although the key is up.

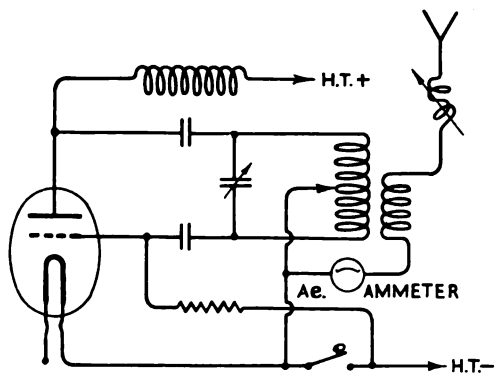


FIG. 2.

In the I.C.W. position of the switch, the grid is keyed in the same way, but a suitable interrupter mounted on the H.T. generator serves to break the H.T. supply at a frequency of approximately 750~.

The generator used in conjunction with the set is of the A.D./B.4 type and delivers a H.T. supply of 1,000 volts at 75 milliamperes, and an L.T. supply of 7·5 volts at 4 amperes, at a speed of 3,500 r.p.m.

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THE TRANSMISSION UNIT

The use of the "Transmission Unit" as a measurement of the power loss along a line is becoming almost universal. It is found, however, that some misunderstanding has arisen as to the reason for the adoption of the unit, and also as to its use.

The following article, therefore, attempts to explain briefly :—

1. *The reason for the use of the T.U.*
2. *The relation between the T.U. and the other units that have been used.*

THE transmission unit (T.U.) was introduced by the Bell Telephone Co. and was given International recognition at the September, 1927, meeting of the International Consultative Committee on Long Distance Telephony at Como.

The International unit was given the name of Bel, which is equal to 10 Decibels, or in other words 10 T.U's.

The new transmission unit was adopted to replace the use of the mile of standard cable which was liable to introduce errors into calculations, primarily due to the fact that whenever the transmission equivalent of a line was obtained by actual test or calculation, the terminations of the standard cable must also be stated, as it is important to know whether the standard cable is free from terminal reflections or has receiving terminations similar to those of the line under consideration.

Also in addition to the volume reduction, there is also a distortion effect introduced by the standard cable. In all carrier and radio work also the mile of standard cable has no significance.

The definition of the T.U. is as follows : "If the power ratio of the input and output power along a line is $10^{0.1}$, *i.e.*, if there is a loss of power in this ratio, then there is said to be loss of 1 T.U. in the line. Similarly, if there is a loss of power in the ratio of $10^{N \times 0.1}$ then we may say that there is a loss of N T.U's in the line."

It should be noticed that the value of $10^{0.1}$ power ratio is midway between the two values which were originally used, namely, $e^{0.1 \log}$ which was used for transmission testing work, and $e^{0.122}$ which is the average equivalent attenuation of voice currents in standard cable.

It should also be noted that the T.U. is essentially a measure of ratio of power and not of voltage or current.

It will therefore be seen that the number of T.U's or decibels loss or gain is calculated by multiplying the common logarithm of the ratio of the input and output

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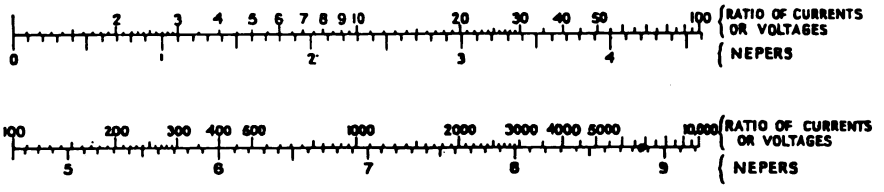
powers by 10, or the input and output currents or voltages by 20. Thus :—

$$\begin{pmatrix}\text{No. of T.U's}\\ \text{or decibels}\end{pmatrix} = 10 \log \frac{Pi}{Po} = 20 \log \frac{Ii}{Io} = 20 \log \frac{Vi}{Vo}$$

NOTE I. In the case of several lines of different characteristics in series with each other, and in other cases where power ratios would, in the ordinary way, have to be multiplied in order to arrive at a final result, it is useful to note that the corresponding T.U's have to be added. This results in a great simplification of calculation in many cases.



NOTE II. There is also a voltage or current ratio unit based on the Napierian or Hyperbolic system of logarithms which differs in value from the Bel and Decibel. The number of "nepers" is obtained as follows, using hyperbolic logs :—

$$\text{No. of nepers} = \tfrac{1}{2} \log e \frac{Pi}{Po} = \log e \frac{Vi}{Vo} = \log e \frac{Ii}{Io}$$

It will be found by a simple calculation that

1 neper = 8·67 T.U's or decibels.

NOTE III. It is also of interest to note the attenuation of a *mile of standard cable* = $e^{.109}$ at 796 cycles per second, whereas the T.U. corresponds to an attenuation of $e^{.115}$, which is in fact the attenuation of a *mile of standard cable* at 890 cycles. For all ordinary telephonic purposes it is convenient to consider that a loss of one T.U. corresponds to the loss on one mile of standard cable, 20 T.U's on 20 M.S.C's and so on.

As this article does not attempt to deal at all fully with the subject of the Transmission Unit, the following references are given for those who are interested and who wish to examine the subject in greater detail :—

M. P. Weinbach. "Principles of Transmission in Telephony." Macmillan, 1924.

H. Martin. "The Transmission Unit," *Jour. A.I.E.E.*, June, 1924.

R. V. L. Hartley. "The Transmission Unit." "Electrical Communication." July, 1924.

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T.U. Conversion Table.

No. of T.U's	Power ratio	Voltage or current ratio	No. of T.U's	Power ratio	Voltage or current ratio	No. of T.U's	Power ratio	Voltage or current ratio	No. of T.U's	Power ratio	Voltage or current ratio
1	1·26	1·122	11	12·6	3·55	21	126	11·22	10	10	3·16
2	1·58	1·26	12	15·8	3·98	22	158	12 6	20	10^2	10
3	2	1·41	13	20	4·46	23	200	14·1	30	10^3	31·6
4	2·5	1·58	14	25	5	24	250	15·8	40	10^4	100
5	3·16	1·78	15	31·6	5·62	25	316	17·8	50	10^5	316
6	3·98	2	16	39·8	6·3	26	398	20	60	10^6	1000
7	5	2·24	17	50	7·1	27	500	22·4	70	10^7	3160
8	6·3	2·51	18	63	8	28	630	25·1	80	10^8	10000
9	7·95	2·82	19	79·5	8·95	29	795	28·2	90	10^9	31600
10	10	3·16	20	100	10	30	1000	31·6	10	10^{10}	100000

The scale connecting Current and voltage ratios with nepers is taken from "Les Filtres Electriques," by Pierre David. Publishers: Gauthier-Villars et Cie, Paris.

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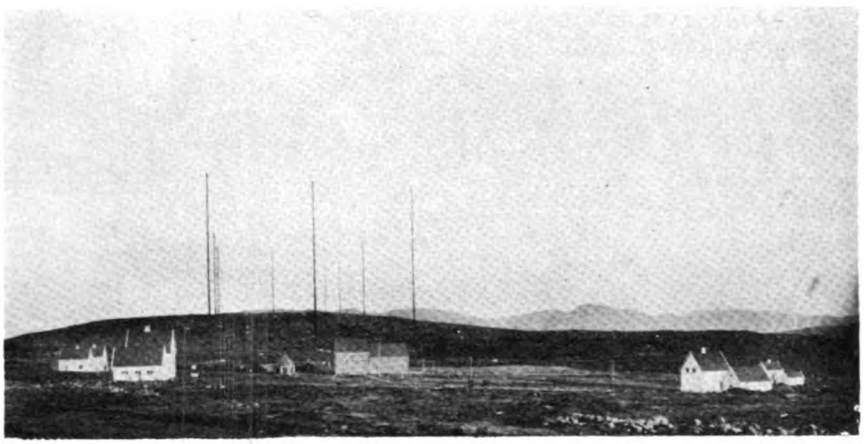
MARCONI NOTES AND NEWS

NORSK MARCONIKOMPANI'S TENTH ANNIVERSARY



STAVANGER WIRELESS STATION, *the Norwegian wireless station which carries on long-distance wireless communication*

The Norsk Marconikompani has celebrated the 10th anniversary of its establishment by the publication of an attractive brochure sketching the history of the company and the part it has played in the advance of the art of wireless.

This brochure is attractively produced and is illustrated with photographs of Senatore Marconi and Directors of the Norsk Markonikompani, together with photographs of the Company's offices and works, of the airship "Norge" and Norwegian ships fitted with Marconi apparatus.

The first ships in the Norwegian mercantile marine to introduce the Marconi system were Fred Olsen's boats on the Oslo-Newcastle route in 1900. In the same year Messrs. Storm, Bull & Co., of Oslo, became the Marconi Company's general agents for Norway, and as a result of this step great progress was made, Marconi wireless stations being installed on a number of mercantile vessels and warships. Courses of training for radio telegraphists were arranged to meet the needs created by these developments, and even during the War the Marconi Agents were able to meet the requirements of radio material for the Army, Navy and the Mercantile Marine.

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Senatore Marconi's sensational triumph in bridging the Atlantic in 1901 gave the late Director of Telegraphs Heftye the idea of establishing wireless communication between Norway and America. At that time Norway had not even a direct cable over the Atlantic and was dependent on other countries for this communication. The establishment of a cable was out of the question owing to its cost, but the building of a wireless station held out the possibility of direct telegraph communication between Norway and the United States and other countries at a cost which was within a figure that could be contemplated. As a result of the State's negotiations with the Marconi Company Stavanger Radio was established, though its operation for commercial services was postponed, owing to the war, until 1919. This wireless station has been of the greatest value to Norway and has been instrumental in strengthening to a high degree the bond between the home-land and Norwegians who have emigrated to other parts of the world.

Since the opening of this station practically all Norwegian telegraph traffic with America has passed through Stavanger Radio.

The Formation of the Company.

Technical development went forward with such great strides during the years of the war that it was natural for Norway in common with other countries to contemplate the utilisation of the Marconi Company's patents on a national basis; and in September, 1928, the Norsk Marconikompani was formed. The requisite share capital was subscribed immediately, to a considerable extent by Norwegian shipowners, and the Norsk Marconikompani began its activities on January 1st, 1919.

Norway was thus the first Scandinavian country to establish a Marconi Company, a matter of great importance having regard to its leading position in the domain of shipping in Northern Europe.

The Company's Managers for the first year were Messrs. Storm and Bull, who had performed meritorious work in the development of the Marconi system in Norway prior to the establishment of the Company. That firm gave up the Management in 1922, and since that date the Chairman of the Board has been Norway's senior shipowner, Mr. Otto Thoresen, whose rich experience in the world of shipping has been a valuable support to the Company. Engineer E. Skottun, who had been connected with Storm, Bull & Co., since 1910, as chief of the firm's technical department, was appointed Managing Director of the Company. He has thus participated in the building up of the Marconi system in Norway for 18 years, during which period about 400 Norwegian ships have been fitted with Marconi apparatus. In recent years the Company has manufactured wireless apparatus for the Norwegian Mercantile Marine in collaboration with the parent company in London, association

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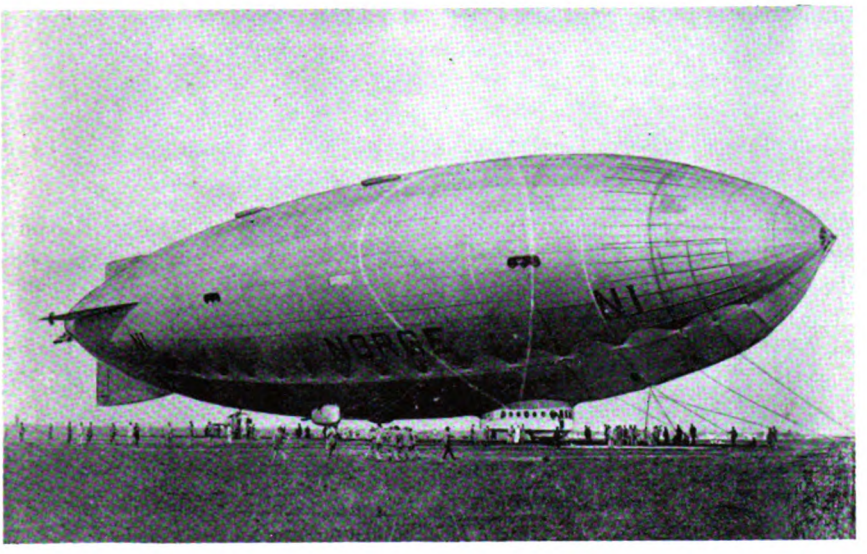

The Airship "Norge" which was fitted with Marconi wireless transmitter, receiver and direction finder for its Arctic expedition

with which has been of the greatest benefit to the Norwegian Company, who have thus been able to avoid costly experiments and to benefit by the parent Marconi Company's greater experience. Another advantage of this has been that it has been possible to adjust the Norwegian installations to Norwegian conditions.

Wireless on The Norwegian Whaling Fleet.

One of the most important activities of the Norwegian Company has been the fitting of ships of the Norwegian whaling fleet which carries on an important Norwegian industry in the Antarctic.

The Norsk Marconikompani also operates a great number of wireless stations on working contracts with shipowners, these vessels including all passenger ships to America and the regular cargo vessels, together with most of the floating whale factories and whale catchers where effective radio communication is demanded. These ships further enjoy the advantages of the Associated Marconi Companies' organisations, such as the repair of wireless equipment in foreign ports and special traffic facilities.

An important development in 1923 was the installation of a powerful radio station on the whaling factory ship "Sir James Clark Ross." The demands on this installation were very great, as the ship was operating in waters thousands of miles from any radio station. Its operation, however, was extremely satisfactory, and the

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communications of the expedition with the outer world were never interrupted. Marconi telegraphists who accompanied whaling expeditions the following year began testing with short waves which then seemed to offer great possibilities, and in 1925 the " Sir James Clark Ross " succeeded in bringing about the first short wave communication over the Pacific Ocean to San Francisco, 8,000 nautical miles away, an achievement which created world-wide interest.

While none of the Norwegian coast stations possessed short wave equipment, Bergen Radio was fortunate in having a chief who was greatly interested in short wave communication, and on February 11th, 1927, a series of communications was initiated between the Marconi station on the " Sir James Clark Ross " and Bergen Radio. Subsequently, the Norsk Marconikompani installed a number of short wave stations on some of the larger passenger ships and on a number of whale factory ships so that these might at any time be in direct communication with Bergen Radio a matter of great importance from a social and economic point of view for a country like Norway with great marine and whaling interests, but without telegraph, cable and coast stations of its own abroad.

Wireless Telephony.

The first wireless telephonic communication in Norway was established between two experimental stations imported from England in 1920. These were installed at Oslo and Horten, and it was between these two places that speech by wireless was heard for the first time in Norway.

When in 1926 the Marconi Company constructed telephony stations for the use of whalers these were immediately introduced to the Norwegian whaling fleet, together with Marconi direction finding sets, and have since given excellent service. The Managers of the whale factory ships can now telephone to the various whale catchers of their fleet and by means of their wireless direction finders can determine the location of their vessels even in fog and in bad snowy weather.

The Norsk Marconikompani's head office and works are at Oslo, while it has a divisional office in the west of Norway at Bergen. The present Board of Management consists of Messrs. Otto Thoresen, shipowner of Oslo (Chairman), Laurietz Kloster, shipowner of Oslo, J. Bull, a mining manager at Horten, E. Skottun, Managing Director, with whom are associated Senatore Marconi and Mr. F. S. Hayburn, Deputy Managing Director of the Marconi International Marine Com munication Co., Ltd., of London.

A large number of letters have been received by the Norsk Marconikompani congratulating it on attaining its tenth anniversary, expressing appreciation of the important work it has carried out, and paying tribute to the leading position this Company holds in the Norwegian commercial world.

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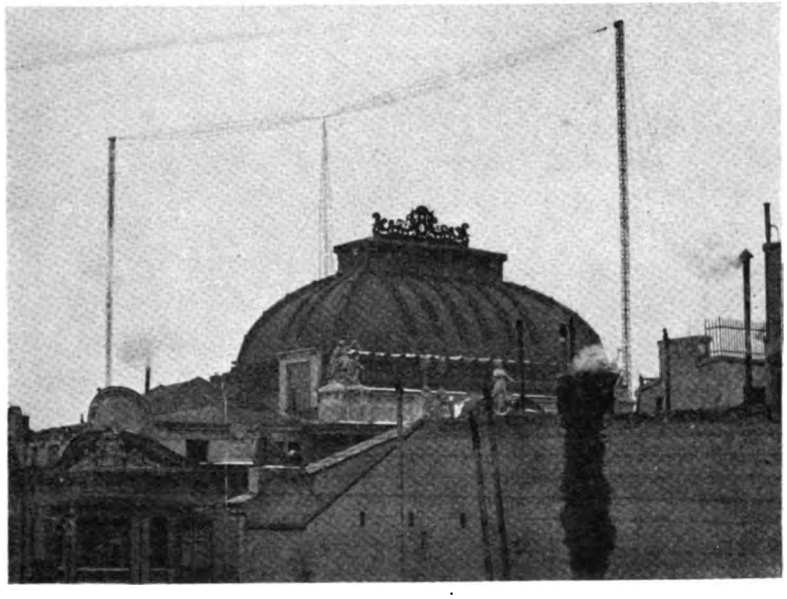

Aerials of the Belgrade Broadcasting Station

Belgrade Wireless Station.

A further report which has come to hand on the transmission of the new 9 kw. broadcasting station, erected by the Marconi Company in Belgrade, is worth recording. This is from Mr. Alfred Magri of Malta, who reports that with a valve receiving set he receives Belgrade much more clearly than other stations of greater power on the Continent of Europe. When he first heard the station announcing he said he could not think to what powerful station it belonged as he had hardly ever heard such a strong and powerful station calling. Both speech and music were exceptionally clear and strong in all instances, the passage from one key to another being perfect, and from beginning to end, talks, announcements and music being in perfect modulation.

Short Wave Broadcasting Transmitter for Italy.

The Italian Broadcasting Company has authorised the Marconi Company to proceed with the manufacture of a short wave broadcasting transmitter for Italy.

The Marconi Company has had considerable experience in the technique of short wave broadcasting through the operation of the short wave station (5 SW) at Chelmsford. The Italian Station will to a large extent follow the design of 5 SW and will enable the Italian Broadcasting Company to carry on a broadcasting service for the Italian Colonies.

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Italy will thus be one of the first countries to make special provisions for its Colonies in its broadcasting organisation.

Communication with Belgian Colonies.

Another instance of the importance attached by European countries to direct wireless communication with their Colonies is the order just placed on the Marconi Company by the Société Belge Radioelectrique, on behalf of the Belgian Government, for a Short Wave Telegraph-Telephone transmitter which will be used for communication between Belgium and the Belgian Congo and Belgium and South America.

Two short-wave receivers of the latest type, similar to those used in the Marconi Beam stations, have also been ordered.

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THE MARCONI REVIEW

June, 1929

CONTENTS

A Study of Wave Synthesis by Mechanical Means—I - - - - - - - Page 1

A Short Wave Aircraft Receiver. Type A.D.20 - - - - - - - „ 9

An Investigation of Short Waves - - „ 13

A Wireless Beacon Cabinet Transmitter. Type W.B.2 - - - - - - - „ 24

Marconi News and Notes—

Wireless D.F. in Fog - - - - „ 29

The Excellence of G5SW. - - „ 31

Wireless for Entertainment at Sea - „ 32

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD.

Marconi House, Strand, London, W.C. 2

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THE MARCONI REVIEW

No. 9. *June, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS

PART I.—DESCRIPTION OF THE APPARATUS

Wave synthesis concerns the building up of a complex wave from simple harmonic waves, and it is, therefore, the opposite of wave analysis. Generally speaking, one is not so concerned with the former as with the latter, which is fortunate, for the analysis of any complex wave can fairly easily be carried out with the help of mathematics, and mathematical expressions for the most complex of waves are straightforward. It may be suggested that the reverse must hold and that mathematics can also express the synthesis of a group of simple waves. This is so in one sense, but in the particular subject with which the present paper deals, we are concerned not with the synthesis wave as a whole, but with its envelope (more strictly its rectified envelope), the shape of which is of the greatest importance.

Unfortunately in respect of this envelope shape, in some cases mathematics are quite unable to assist, at least so far as giving any lucid ideas on the subject; and it was with the idea of being able to study this feature, as well as for the purpose of demonstrating the general principles of wave formation to Students at the Marconi School at Chelmsford, that the author devised the mechanical model about to be described.

The paper will, for convenience, be divided into the following two parts:—

(1) *Description of the Model and its method of operation.*

(2) *Uses to which the Model may be put, in particular those relating to wireless practice.*

---

(1) DESCRIPTION OF THE MODEL AND ITS METHOD OF OPERATING.

Preliminary.

BEFORE designing the present model the author explored the many ways in which instantaneous values of motion may be integrated mechanically, and after some preliminary experiments, came to the conclusion that the principle adopted by Lord Kelvin in his tide machine was by far the simplest and

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most suitable method to work upon. This delightfully simple principle involves integration by means of a connecting cord and from Fig.1, which shows two motions to be added coupled by the connecting cord, the rough idea can be followed.

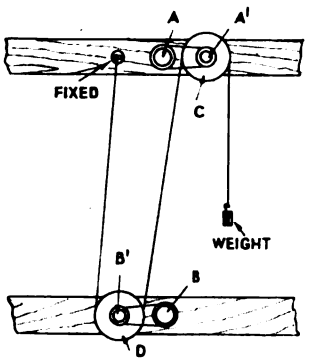

FIG. 1.

The cranks A and B, which can be moved as required, give the motions to be added, and in general they will be rotated at constant speed so as to provide sources of harmonic motion. The crank pins A′ B′ support loose pulleys C and D, over which runs the integrating cord. One end of this cord is attached to a fixed point whilst the other end hangs free, is weighted, and can hold a marking point. Due consideration of the system shows that the movement of the free end of the cord will sum the movements of the cranks, provided the rotation of the top crank is opposite to that of the bottom crank, or alternatively that they are set in antiphase.

Thus if a slip is passed laterally across a marking point held by the free end of the cord, a linear record of the resulting waveform would be obtained, although actually the movement of the free end of the cord gives double the sum of the individual movements, because we have here the second order of pulleys; hence if a correct amplitude record is required some form of reduction system is necessary.

General Features.

In designing the Model certain important features had to be borne in mind. The machine was to be of use largely for demonstration and instruction and not so much for the purpose of obtaining strictly accurate results. An important feature for demonstration which is unimportant otherwise, is that all component frequencies must draw out their trace simultaneously with the resultant. Further, these traces should all mark at the same relative position on a "time" base. Another feature is that the working model should give a good visual idea of the process and provide some clear mental pictures of the meaning of wave synthesis.

General Description—Motions Used.

Referring back to the elementary cranks given in the first figure, it can be seen that if the amplitude of any crank is at all large, the top and bottom motions would need to be spaced a very great distance apart if any accuracy is required; otherwise the sideway motion given to the loose pulleys would throw the cord out of vertical alignment and an undesired alteration of cord length would result. To get away from this undesirable feature and in order to obtain a correct trace of the component frequency an infinite connecting rod motion is used.

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This is shown in Fig. 2, and using this type of crank and rod motion, the top and bottom rows of pulleys need to be spaced only the width of the recording paper apart. Such a design also enables adjacent cranks to be mounted quite closely together.

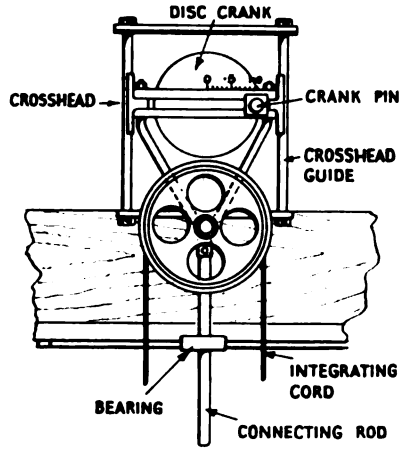

FIG. 2.

The model is arranged to add six component frequencies and so designed that the six frequencies involved lie in line and not opposite one another. The advantage of this is that phasing of each component is clearly defined, and one has no reversal to worry about due to position.

Fig. 3 shows the front elevation of the model from which most of the general features can be seen. The component harmonic motions are obtained by continuously rotating cranks, and the six disc cranks 1 to 6 with their link work are seen to be mounted in line upon an upper horizontal beam. The crank pin for each motion is adjustable and amplitudes from 0 to 1·0″ can be obtained. In the original model the following arrangement was made for obtaining any desired amplitude. The face of each disc crank was drilled across two diameters with a succession of holes. These holes were staggered so as to obtain a series of amplitudes from ·05″ to 1·0″ in steps of ·05″. If it was desired to get amplitudes between ·05″ this was done by means of an eccentric crank pin. Thus means were provided for obtaining any amplitude between the limits.

In the present design of this machine shown in the photograph an improved arrangement has been adopted for obtaining a gradual variation of amplitude. This consists of slotting the face of the disc with a mortice shaped groove and providing a sliding which can be locked in any desired position by the crank pin. The amplitude position is observed by a pointer indicating on an engraved scale.

The design of the crosshead and connecting rod is such that the latter moves with true harmonic motion and hence a marking point attached to the connecting rod will give an accurate record of the movement of the crank pin.

Linkwork.

In order that each component frequency may mark at the same position on the "time" base, every connecting rod carries a rigid light drilled aluminium angle piece, I, which can be locked to the connecting rod in any desired position in the vertical plane by milled headed screws. The end of this aluminium rod holds a

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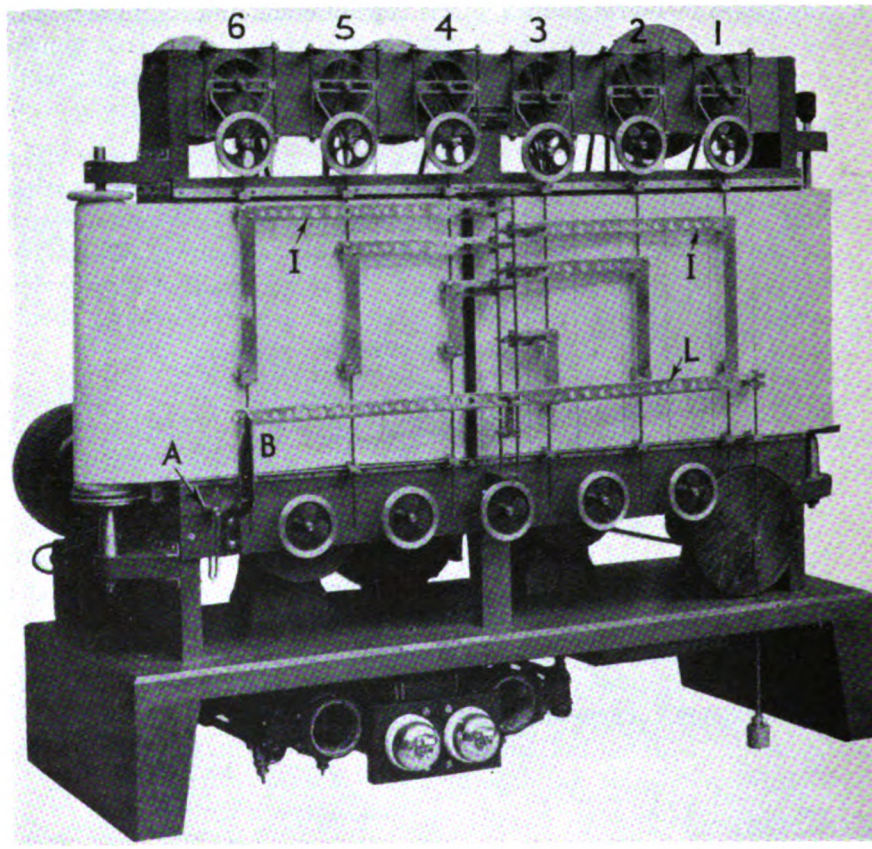

FIG. 3.

small brass cylinder pointing to the board into which a pencil holder is slid, pressure being obtained on the outer end of the pencil by a light steel adjustable spring designed to give constant pressure.

To take the outward thrust due to the pencil an additional steel spring is attached to the end of the holder in the form of a bow, the back of the bow bearing on the inner edge of a vertical rod. Thus no torque has to be taken by the connecting rod, the pencil pressure being counteracted by corresponding pressure immediately behind it and therefore in line with it. In spite of the length of pencil arm (the longest is 15″) there appears to be no appreciable whip at the pencil as can be seen by the records taken, although of course any inaccuracies here do not affect the resultant curve in any way.

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The two rods taking the back pressure of the six pencils (three on each side) are also used to carry the pencil slider of the integrating motion and this constrains the motion of this pencil to a vertical plane.

The loose pulleys carrying the integrating cord are attached to the cross head forks and hence these loose pulleys will only move in a vertical plane. By such a design no inaccuracy due to misalignment of the cord out of the vertical will result, and the model has been kept more campact.

Attached to the lower edge of the model board is a second set of loose pulleys which are simply to make the necessary reversal of cord direction between successive cranks.

Integrating Cord.

The fixed end of the integrating cord is attached to a slotted strip for adjustment, shown by A, and after running over all the loose pulleys the end of the cord is held taut by a weight of something under half a pound ; this is found quite sufficient for most purposes and at the highest speeds used no noticeable jumping occurs.

To obtain good results, it is necessary to use a cord which will not stretch in any way, but at the same time it must be perfectly flexible, and the cord adopted consists of a stranded phosphor bronze wire consisting of nineteen strands of No. 42 gauge wire laid up like a Bowden cable, that is, with reversed lay so as not to stretch or twist. The choice of this wire resulted after trial with cords of many types and it is found satisfactory.

Integrating Arm.

When considering the action of the model it was shown that the amplitude of the end of the integrating cord was double the correct amplitude and hence to obtain a record to scale, a reduction gear of 2 to 1 must be used. The long aluminium strip " L " shown in Figure 3 across the face of the model is the integrating arm, this arm being pivoted on a pin attached to the bracket " B," its other extreme end being linked to the cord. The centre of this arm is slotted and through the slot a pin is attached to a pencil slider, and so arranged as to fall in line with the other pencil holders. Thus the former moves at half the amplitude of the end of the cord, the guide rods previously mentioned as giving pressure support to the pencil holders, keeping its movement in a vertical plane. As the length of arm is so great it is not strictly necessary to provide horizontal sliding motion for the arm attachment to the cord, although in the present model this refinement has been introduced.

Of course, should it be desired to obtain a resultant record of greater amplitude than is correct, this can be done by fastening the marking point to any desired

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position between the centre of the arm and the free end, although it is pointed out that the phase of the resultant wave will have to be corrected for on the slip.

Method of Driving Cranks.

The method of driving each component crank can be seen clearly from Fig. 4, which shows the model set up for the demonstration of a square wave. In this case all six cranks are in use, of frequency 1, 3, 5, 7, 9 and 11.

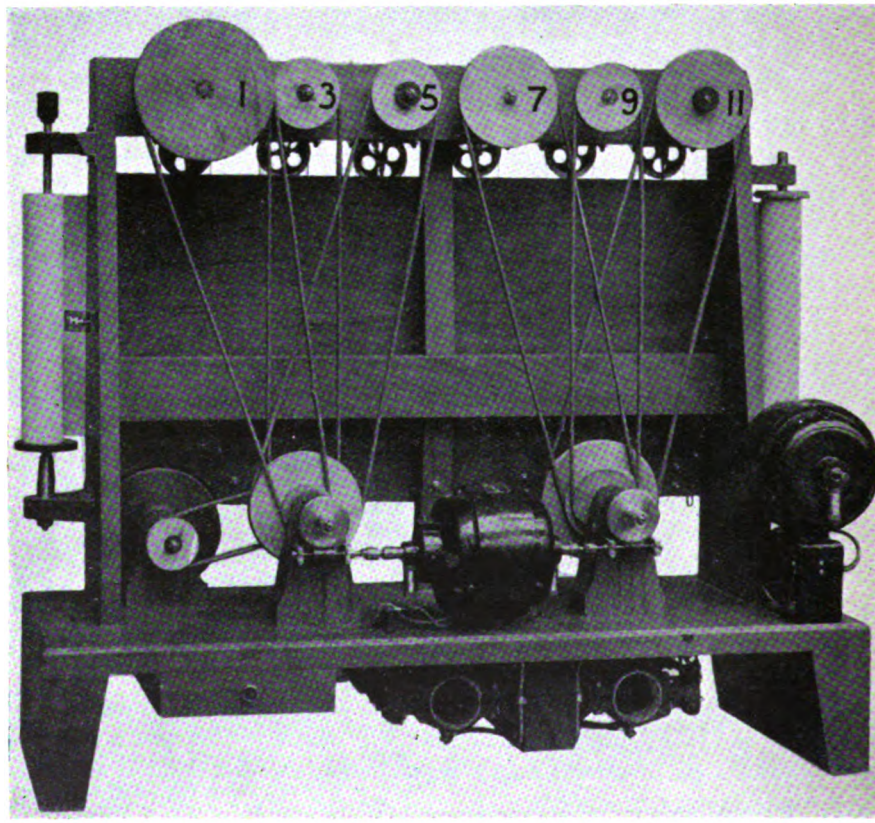

FIG. 4.

A small motor drives two countershafts through worm gearing which can be altered as desired. Each countershaft in turn can feed three cranks by leather belting and ordinary grooved pulleys. These belt drives after a certain amount of experiment have turned out entirely satisfactory and constant speed for a very considerable number of revolutions can be obtained. At one time it was feared

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they were introducing a variable error but this has since been disproved and they can now be said to be operating in an entirely consistent and satisfactory manner.

The secret of successful working lies in making the pulley grooves rounded so that the belt definitely beds on the bottom and just takes up some of the drive on the sides.

In order to make demonstrations of various phenomena it is, of course, necessary to change the various pulleys and gear wheels of the driving system and a quick standard method of fitting these pulleys has been adopted, which is of interest. Squares are always unsatisfactory for driving, as it is almost impossible to fit them accurately, taper shafts are sound but there again accurate fitting is necessary and expensive, and they do not allow lateral movement, so a split shaft method is used.

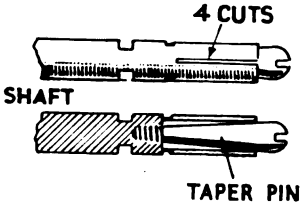

FIG. 5.

The ends of all driving shafts are made to a standard diameter and hollowed out. They are turned to a neck along the shaft, then split and a taper key screwed into the end of the shaft so that after a pulley has been pushed on, it can be locked by tightening up the taper key, the detail of this arrangement being as shown in Fig. 5. This forms a very quick and accurate method of fitting the driving pulleys.

Drive and Paper.

A vertical board between the top set of cranks and the lower set of pulleys provides a surface across which the indicator paper is racked. This paper is twelve inches wide and ordinary drawing office detail paper is used, a standard roll being cut into three for the purpose. The roll is slipped on to a disc with a short coned axle, and a steel rod dropped through the centre of the roll on to the coned axle, holds the roll in a vertical plane, provision being made by the fitting for easy rotation. Suitable spring tension is provided against the surface of the roll to prevent the record from bulging across the surface.

The drum drawing the paper across the board is located on the opposite side of the model and this drum is rotated by means of a separate motor worm drive of 200 to 1 reduction. A separate motor is essential in order that records can be "opened out" or "closed up" as desired. A free wheel attachment (simply a taper pin) is embodied in the drum so that any paper record can be unrolled from the drum without difficulty.

In order to keep the paper perfectly flat against the board as it passes the marking points (which move in a vertical plane) a polished ebonite roller is used,

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which is held tightly against the board by two flat springs pressing on to its end bearings. This is shown in Fig. 3 at the centre of the model.

Marking Points.

The method of recording in the present model is by means of ordinary lead pencil. Short pieces of pencil are fitted into the ends of small brass cylinders, the latter being fitted to the various holders on the model, as previously described. In order to obtain a clean record, a highly buffed hard brass strip is let into the face of the record board in line with the pencils, the record paper running across the surface of this polished strip.

There appears to be much uncertainty about the relative merits of ink and pencil recording for a model of the type described, but from the records obtained the pencil has proved very satisfactory on the whole.

Objections to pencil recording are :—

(1) The pressure requires to be fairly great.

(2) The record is not permanent (although it can be made so).

(3) The record is not too visible.

(4) Pencils have to be sharpened frequently as only a soft lead (B) of (HB) can be used.

Objections 1 and 2 can be overcome, whereas objection 4 does not enter into the present case very much as only short records are ever required.

Ink recording would have got over the above difficulties but there are two serious objections to the use of ink which prevented its being adopted.

First, in the case of the reproduction of curves such as are obtained for modulated waves, the paper is run very slowly and as the motion changes rapidly the curves are run very much together, so much so that any type of ink recorder would "smudge" for a considerable part of the cycle. Further, the present model is used only at intervals, for a few minutes at a time, and hence recording pens, if used, would have to be cleaned out each time in order to prevent them from drying up.

Chiefly therefore, on account of these two reasons, pencil recording was decided upon and except for the fact that the record is not as visible as it might be, it has been found satisfactory.

A. D. LADNER.

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A SHORT WAVE AIRCRAFT RECEIVER

TYPE A.D.20

In the last number of THE MARCONI REVIEW, *a short account of the A.D. 21 aircraft transmitter was given, and it was there mentioned that this transmitter was intended for use in conjunction with the Type A.D. 20 receiver, a description of which is given below.*

The employment of short waves for aircraft communication has the advantage that fixed aerials can be used, thus enabling service machines which normally fly in close formation, and fighting aeroplanes to use these sets, since no trailing aerials are present to hinder the manœuvring powers of the aircraft.

TWO editions of the Marconi Receiver Type A.D.20 are made—the A.D.20 and the A.D.20A. The first of these has a waverange of 40–60 metres, and the second of 80–180 metres. As the design of these two are almost identical, it will be sufficient to describe the A.D.20 in detail and to point out in what respects the A.D.20A differs from it.

The receivers are suitable for the reception of continuous wave, interrupted continuous wave, and telephony signals, and have been designed with a view to providing an efficient instrument for the reception of short waves in aircraft of all types.

Simplicity and ease of operation have been the first consideration in the design of these receivers. The ignition system of the aircraft is more likely to interfere with reception on short wavelengths than on long wavelengths, and it is therefore necessary to pay particular attention to the efficient screening of the whole of the engine ignition system.

The receiver is contained in a copper-lined box which forms a complete electrical screen to prevent as far as possible direct pick up in the tuning coils, and to eliminate hand capacity effects. The box itself is made of metal, fitted with a removable front. The removable front covers an aluminium panel which carries the various receiver controls.

A photograph of the set is shown below and the position of these controls, etc., will be obvious.

Aerial System.

The receiver may be used with widely varying forms of aircraft aerial.

It is designed to be extremely flexible in this respect and a fixed aerial may be used, firmly attached to the structure of the aircraft, and supported and insulated

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as far as possible from the wings and fuselage, especially if these be of metal construction.

As the receiver is intended for use with the aperiodic type of aerial, the exact length of the aerial is not important.

Receiver.

A complete diagram of connections of the receiver is given below (Fig. 1), and the general lay-out of the components can be readily understood from this.

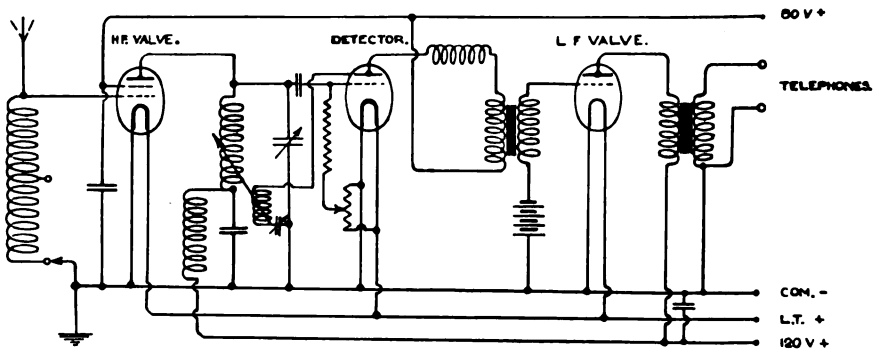

FIG. 1.

The receiver comprises a high frequency amplifier utilising a Marconi Screened Grid Valve Type S.G.215, coupled by means of a tuned anode to a leaky grid detector using a Type D.E.L.210 valve. The single note magnifier is transformer coupled to the detector, and uses a similar type of valve.

The aerial circuit consists of an aperiodic coil, coupled directly to the control grid of the first high frequency valve.

The necessary potential for the screen grid of this valve is obtained by a tapping on the anode battery at 80 volts.

The H.T. supply to this valve is obtained through a choke and tuning coil. This coil is tuned by means of a ·0003 variable condenser. The choke is provided to prevent any feed back of high frequency energy which might possibly cause distortion and oscillation in the later stages of the set. A ·01 mfd. fixed condenser is connected from the bottom of the tuning coil to earth in order to provide a virtual short circuit for all high frequency currents while still keeping the positive high tension supply of the anode from being shorted to earth.

Closely coupled to the tuning coil is the reaction coil from the detector anode. Variable reaction is provided by means of a ·00025 variable condenser. A small

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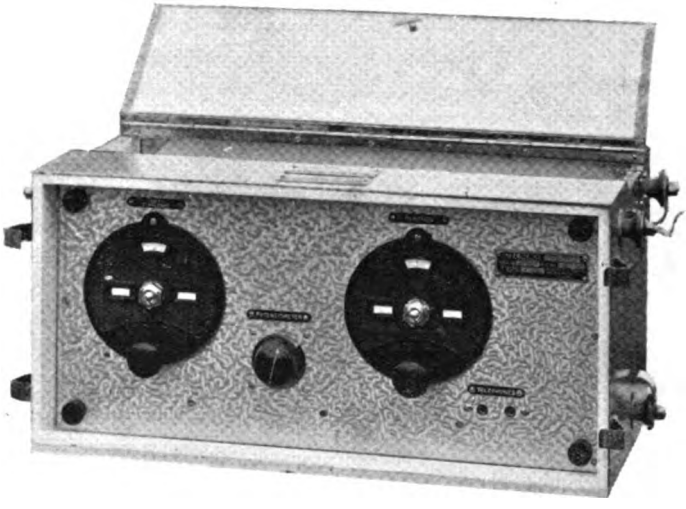
fixed condenser in series with this circuit protects the anode battery should the reaction condenser be accidentally short circuited.



A ·0001 condenser couples the anode of the first high frequency valve to the grid of the detector. The grid leak of this valve is connected to the variable contact of a potentiometer connected across the filament supply in order that the grid bias of this valve may be capable of very fine adjustment, and that best reaction conditions may be obtained.

The detector valve is supplied with high tension current from the 80-volt tapping on the anode battery via the primary of the intervalve transformer of the note magnifier and a high frequency choke. This choke is provided to prevent high frequency oscillations being fed back through the anode battery.

The third and last valve operates as a transformer coupled note magnifier. The circuit of this is quite normal and needs no special description.

A 9-volt grid battery is provided in order that the grid of this valve shall have the correct bias, and may operate at its most efficient point. The correct amount of bias should be from 3–4·5 volts when using a D.E.L.210 valve.

As the set is intended for use with low resistance telephones, a telephone transformer is provided in the anode circuit of this valve, and one side of the secondary of this transformer is connected to earth.

Batteries, Cables, etc.

The batteries provided for use with the set consist of a H.T. dry battery of 120 volts with an 80-volt tapping carried in a tray underneath the receiver, and a 4-volt accumulator carried in a box fitted with fuses and terminals.

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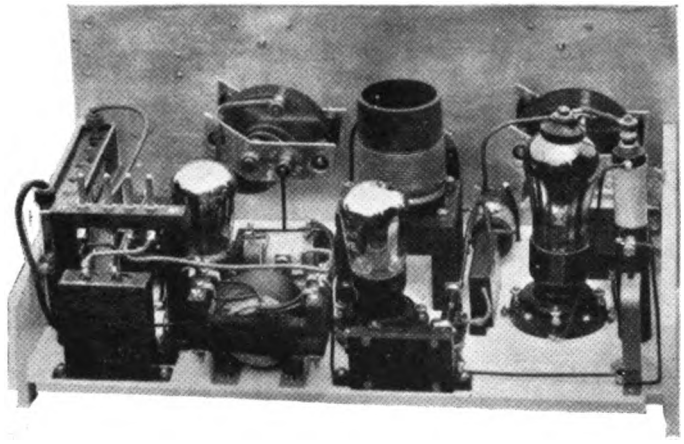
These batteries are connected to the receiver by a 4-way cable passing through a slot in the right-hand side of the instrument box and terminating in a 4-point socket which is connected to a corresponding plug mounted in the receiver box. A tumbler switch is provided for inserting in the low tension positive lead in order that the filaments may be switched off when the receiver is not in use.



When the receiver is used in conjunction with a transmitter the receiver accumulator may be dispensed with if desired, and the receiver L.T. leads connected across part of the transmitter L.T. accumulator, the negative lead being always connected to the negative terminal of the battery.

Operation.

The operation of the receiver is extremely simple as there are so few controls.

Signals are tuned in by the left-hand condenser and the receiver brought up to the oscillating point by varying the right-hand or reaction condenser control.

A calibration chart is provided in order that the receiver may be tuned approximately to the required wavelength thus facilitating searching.

Smoothness of reaction control is of the greatest importance in a short wave set, and it will be found that in the case of the A.D.20, the use of the potentiometer in conjunction with the reaction condenser allows the receiver to slide very smoothly into reaction.

A.D.20a.

The A.D.20A receiver is exactly similar in design to the A.D.20 with the exception that different windings are provided on the tuned anode and reaction coils.

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AN INVESTIGATION OF SHORT WAVES*

By T. L. ECKERSLEY, B.A., B.Sc.

The following article is an abstract of a paper read before the Institution of Electrical Engineers on April 10th, 1929, by the present author. The conclusions arrived at are based on the results of a systematic study of signal strengths and signal directions from a number of stations observed over a period of twelve months by the Research Department of the Marconi Company.

One of the most useful results of the author's investigation is the explanation which it offers of the observed deviation of the bearings of Beam Stations from their true values. This is given in detail below, and is consistent with the theory forming the latter part of the original article, which has been omitted from this abstract for the sake of brevity.

In addition to this, two important conclusions are reached:

(1) *The existence of the phenomenon known as "scattering" of short wireless waves is placed beyond doubt.*

(2) *The previous conception of the Heaviside layer must be altered to conform to the latest experimental results obtained.*

Scattering.

IN a recent paper before the Institution of Electrical Engineers, the writer described results which indicated that short wireless waves were quite appreciably scattered in traversing the Heaviside layer. The effect of such scattering is to blur the dots and dashes of Morse signals and is therefore of importance in certain circumstances in high speed signalling.

Although blurring and short echoes are a symptom of scattering, the best method of investigating scattering is by means of suitably designed direction finders, and the results have been obtained largely by their use. Tests originally made years ago and described in a paper on Short Wave Transmission, in which a balanced frame and vertical aerial were used, indicated the probable presence of scattering in the skip region, but they were not decisive for, owing to the practical limitations in the size of the vertical aerial or coupling between this and the frame, it was not certain whether the observed absence of bearing was really due to the incidence of scattered radiation or whether it was due to radiation of such high angle that the balance adjustment was outside the limits obtainable on the apparatus.

An unequivocal test was arranged as follows: Two vertical aerials were used, set up at a distance apart of 13 metres and finally 30 metres. The object was to balance the effect of the two E.M.F.'s induced in the two aerials, and the circuit used for this purpose is shown in Fig. 1. A and B are two aerials, each tuned and loaded with similar inductances. The received energy is brought from the two aerials by two buried cables C_1 and C_2, the inner conductor being tapped up two turns of the inductances L_1 and L_2. The power from the two cables is delivered to two tuned circuits S_1 and S_2 by means of a tapping connection so adjusted that the impedance between T_1 and T_2 is the surge impedance of the cable. A reversing switch S was inserted between one of the cables and the tappings T_1, T_2. Each of these circuits was coupled to a coil forming part of the input circuit of the amplifier. The relative coupling between this and the two circuits could be varied by moving the coil across from one to the other.

* Abstract of Paper read before the Institution of Electrical Engineers, April 10th, 1929.

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In considering the acton of this system, the simplest case is where the trace of the ray (supposing a definite ray to exist) is perpendicular to the line joining the two aerials. The currents induced in these two will then be in phase, and if the cables are made to be the same length the current in the two tuned circuits will also be in phase and the effects of the two can be added or subtracted in C by reversing the switch S. A slight adjustment of the position of C will enable the two to be balanced. If, however, the trace of the ray makes an angle with the normal to the line joining the two aerials, the currents in these will no longer be in phase, but this effect can be compensated by slightly mistuning each of the two tuned circuits S_1 and S_2, one longer and one shorter, so as to produce the requisite difference in phase.

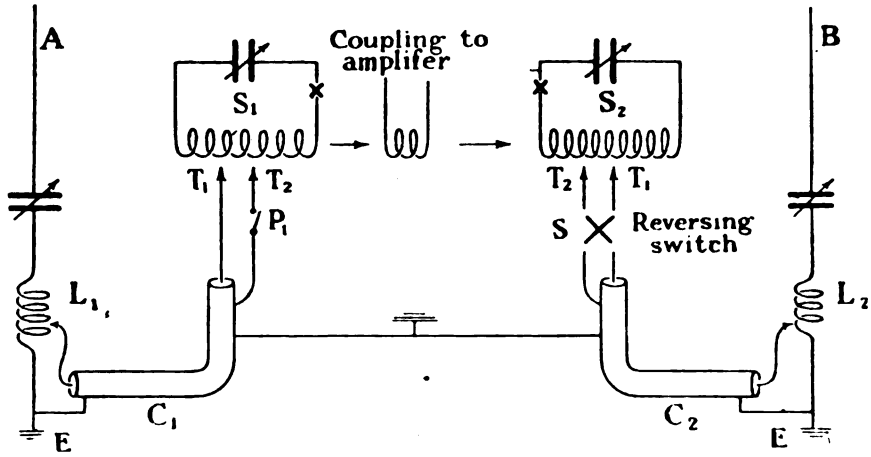

FIG. 1.

In this manner signals from any station not too nearly in line with the aerials can be balanced, provided the energy is travelling along any ray or set of rays in the vertical plane.

Results obtained.—The receiver was set up at Broomfield, a little over a mile from the Marconi Works, Chelmsford. Firstly, the signals from local stations, such as the works, Ongar and the Marconi College, could be balanced almost perfectly. The residual signals at the balance point, which were probably due to instrumental imperfections, remained constant and were a very small fraction of the unbalanced signals.

Secondly, the signals from stations within the skip distance, *e.g.*, Bodmin, Grimsby, the Dutch stations (at times), and AGB (Berlin) (at night time during the period of weak signals), could not be balanced with any adjustment of the circuits ; in fact, any station which normally gave no balance on the cardioid receiver also gave no balance on this system.

Finally, long-distance stations, in particular the beams, Canada ($\lambda = 26$), Australia ($\lambda = 25$), India, South Africa, the North American stations (2XT, 2X5, 2XBC), Rio and Java, etc., generally showed an intermediate condition between these two extremes.

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As is well known, the intensity of signals from long-distance transmitters fluctuates enormously in periods of 5 seconds and upwards, changes of intensity of 8 or 10 to 1 being quite common. It was found possible to balance the signals at the peaks of intensity but not at the minima. The balance at the peaks was not perfect, a residual strength of one-sixth to one-tenth of the maximum intensity being obtained; in fact, this residual intensity was of the same order as the intensity at the minima of the fades.

If the switch S was left in the balance position, and the switch P_1 (say) was opened so that signals from one of the aerials alone were received, then if the switch P_1 was closed at a peak value of the signal so as to balance the two aerials, a large diminution of signal strength was observed. At the minimum of the fades, however, no change was produced on closing P_1, nor was there any change if P_1 was kept closed and S reversed.

As far as the author can see, there can be only one interpretation of these results. Close to the transmitting station the direct ray, with its definite direction of travel, is predominant and the signals from the two aerials can be easily balanced. The direct ray is attenuated very quickly, and at distances of a few miles (depending on the wavelength, nature of the transmitting aerial, etc.), this direct ray is swamped by radiation scattered from the Heaviside layer. It is easy to see that no balance can be obtained with this system in a field of scattered radiation, for the position of balance varies with the direction of each ray, and no single position of balance can be obtained, except, perhaps, momentarily when the main bulk of the energy is travelling instantaneously in one direction. On the average (even over quite short periods of time) the currents in the two aerials will be equal but of random phase difference. At great distances the evidence points to the existence of a main ray (which can be balanced on the two aerials) together with a scattered residue which remains when the main ray has faded out. These results were not of isolated occurrences, but were perfectly regular and normal, and they seem to put the existence of some sort of scattering beyond doubt. Scattering in this sense merely implies the existence of energy travelling to the receiver along more than one path in the horizontal plane. It might, as is most probable, be produced in the Heaviside layer, or from irregular objects on the ground, or it might arise rather as a single reflection from some vertical or semi-vertical surface of discontinuity in the Heaviside layer, the resultant two rays in the different horizontal azimuths giving rise to an imperfect balance. In fact the disturbing rays, as we might call those other than that in the great-circle path, may be single or multiple; perhaps the term "scattering" should legitimately be applied only in the latter case and the term "irregular reflection" in the former, though of course scattering is, in its ultimate analysis, an irregular reflection. Perhaps it is best to class the two as single and multiple scatterings. There exist, no doubt, all gradations between the two.

Since the scattered signal travels by a different path from, say, the direct signal (not necessarily direct ray) there will be a time interval between the arrival of the two. The scattered signal may be said to be an echo signal, and the subject may be studied from the complementary point of view of echoes. Photographic records of signals show the existence of echoes of such short delays that they may well be produced by relatively local scattering (using this term in its general sense, as implying multiple paths in the horizontal plane). These short-period echoes have

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been studied chiefly by the Americans, whose results will be used here to supplement our own knowledge obtained chiefly by directional methods.

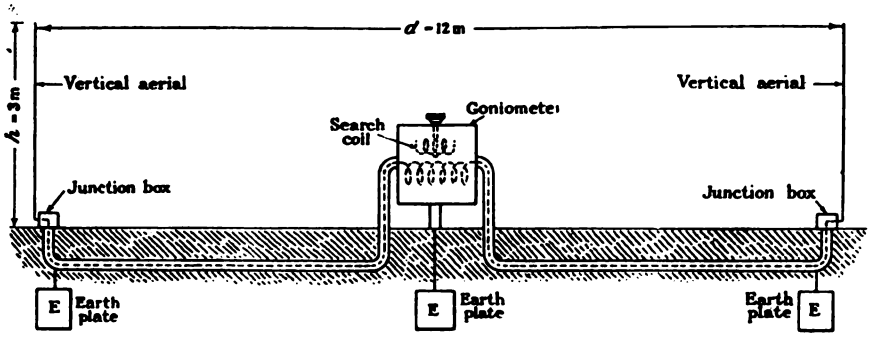

FIG. 2.

The success of the two-aerial system in interpreting transmission results led to the development of a form of goniometer or direction-finding apparatus specially suitable for studying scattering and other transmission effects. It may be worth while to describe it in some detail, as little appears to have been done elsewhere in the application of direction-finding to short waves. Perhaps it should be stated at the outset that the arrangement is better as a means of investigation of short-wave transmission phenomena than as a direction-finder. This is chiefly because of the absence of any marked direction in a large percentage of cases, the main ray along the great circle path being swamped by others.

It was early realised that short-wave direction-finding suffered from the worst kind of what is called "night effect," and that any directional receiver which had any horizontal force "pick-up" was bound to give spurious results. Efforts were therefore concentrated on a device with vertical antenna.

The arrangement employed is known as the Adcock aerial.* It has been used successfully on 400 metres by Smith-Rose and Barfield, and it seemed probable that the difficulties experienced by these workers would be less marked on short waves where the aerials can be spaced at a distance comparable with the half-wave of the signals employed, so that the differential effect between the two aerials was not too small compared with the E.M.F. on one and the balance need not be so carefully maintained.

Four vertical aerials 3 metres high were accordingly placed at the corners of a square 12 metres across the diagonal. These were connected to the core of buried lead cables (direction-finding cables with paper insulation) which were brought to the centre where a suitable shielded goniometer was placed. Each diagonal pair of aerials, cable and primary coil of the goniometer constituted a single circuit, as shown in Fig. 2.

The cables were buried to a depth of about 1 ft. and were well earthed by low-inductance strips to deeply buried earth plates. It is obvious that the E.M.F.

* R. L. Smith-Rose and R. H. Barfield: "The Cause and Elimination of Night Errors in Radio Direction Finding," *Journal I.E.E.*, 1926, Vol. 64, p. 831.

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on each pair depends on the direction of the ray relative to the line joining the two aerials.

Thus the E.M.F. on AB $= E \sin \left\{ \frac{2\pi d}{\lambda} \sin \theta \right\}$

and the E.M.F. on CD $= E \sin \left\{ \frac{2\pi d}{\lambda} \cos \theta \right\}$

and if ϕ is the angle at which the search coil of the goniometer is balanced

$$\tan \phi = \sin \left\{ \frac{2\pi d}{\lambda} \sin \theta \right\} \Big/ \sin \left\{ \frac{2\pi d}{\lambda} \cos \theta \right\}$$

and if $2\pi d/\lambda$ is sufficiently small this is $\tan \phi = \tan \theta$, or $\phi = \theta$ when the coils of the goniometer are connected up properly. It is evident that the success of this arrangement depends on the elimination of any horizontal " pick-up."

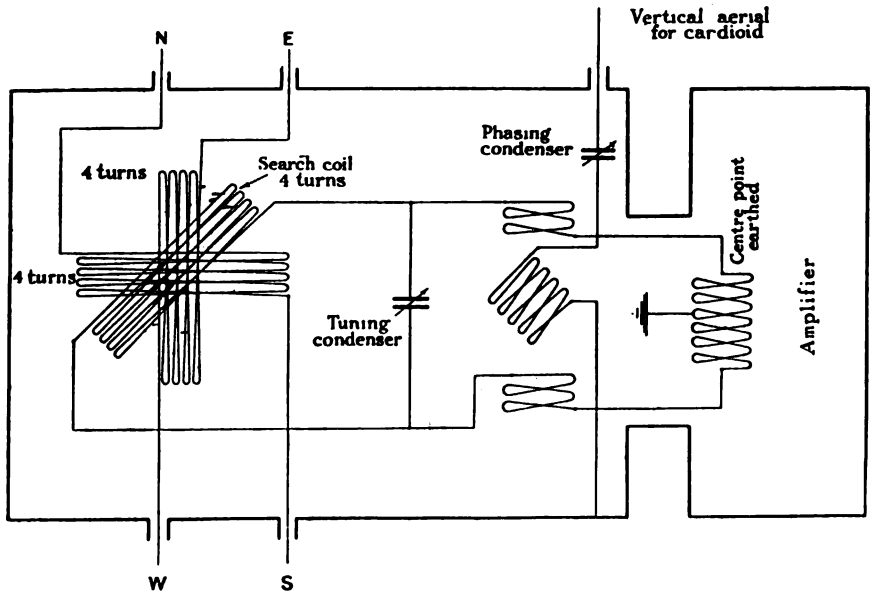

FIG. 3.

It is for this reason that the horizontal cables are buried and carefully earthed at the ends. These precautions seem to be successful, since the swinging of bearings noticed on the frame was almost entirely eliminated. There may be a small residual horizontal " pick-up " remaining.

It was found essential to have the lead of the outer shielding of the cable continuous with the outer shielding of the goniometer, so that the electrical field was wholly confined to the inside of the apparatus.

The goniometer was close-coupled with four turns on each primary and on the secondary (Fig. 3). It functioned quite well between wavelengths of 13 metres and 60 metres. A vertical aerial could be coupled to the search-coil circuit so that a

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unidirectional cardioid diagram could be produced. It will be observed that when $2\pi d/\lambda$ is not small ϕ =/= θ, and there is an octantal error which can easily be derived from the formula given.

It was with this receiver that the main results of scattering have been obtained. It will be realised that this goniometer will give a true bearing whenever such exists and will give no bearing at all in an isotropic field of scattering.

The results obtained with this direction-finder in over a year and a half's work are so diverse and varied as almost to defy classification. Perhaps the most convincing effects were obtained in studying the beams.

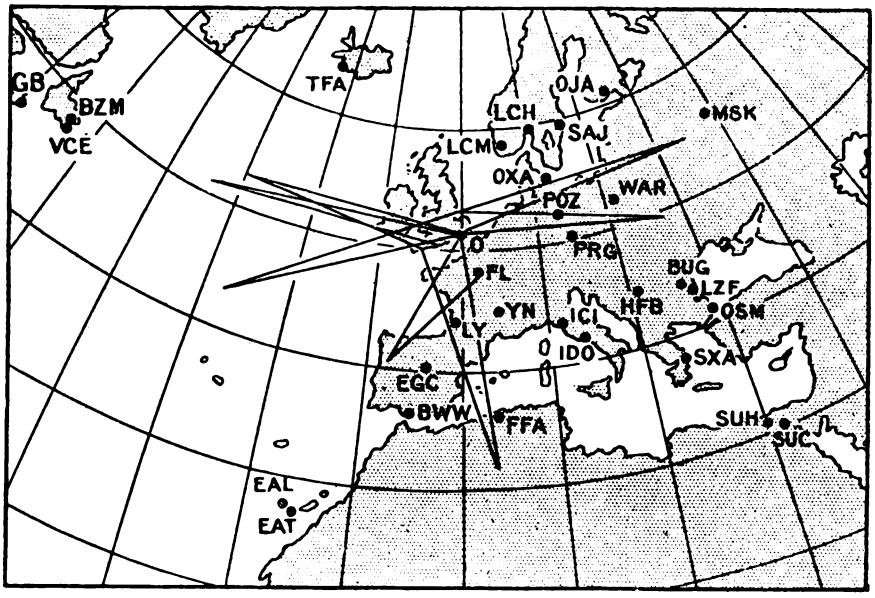

FIG. 4

Fig. 4 is a map showing the locations of the English beam transmitting stations at Bodmin, Dorchester and Grimsby, together with the great circles showing the mean line of the beams sent out (*i.e.*, the great circles to Montreal, South Africa, India, Australia, New York, Buenos Aires, Cairo, etc.). The position of the directional receiver at Broomfield, Chelmsford, is shown at O. The bearings of these beam stations have been observed regularly throughout a period of 9 or 10 months. The results vary from day to day, but it can be said that in practically no case is the true bearing of the transmitting station obtained. Occasionally there is no bearing at all, but in the majority of cases a more or less defined bearing is found which is close to the bearing of the station worked by the particular beam in question. A reference to the map will make this clearer. Take the station at Grimsby (GHB), wavelength 26 metres, working to Australia. The true bearing of this from Broomfield is about 350° or 10° West of North. The actual bearings were found to be as a rule from the West-North-West in the morning and from the East-South-East in the afternoon, and in fact they were close to the true bearings of

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Australia. Similarly the bearing GBJ (Bodmin) working to South Africa was close to the bearing of VNB (S.A.) and so on.

The sharpness of the bearing varied from time to time, and the signals were obviously of the scattered type, *i.e.*, blurred and hollow-sounding, but the bearings were quite definite enough to obtain averages with probable errors of about 3°.

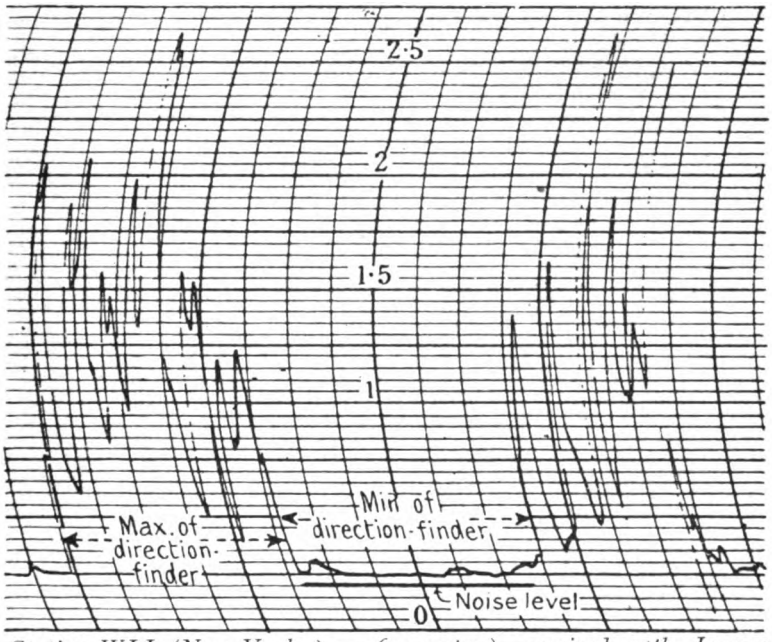

FIG. 5.—*Station WLL (New York, λ = 16·2 metres), received 25th January,* 1928, *on Adcock aerial direction finder. Unscattered signal.*

There was fortunately a sufficient variety of stations to ensure that the above was the general rule. One fact which puzzled the author for some time was that Dorchester (GLW) working to Rio always appeared to give its true bearing, whereas all the others appeared to give bearings nearly at right angles to their true bearings. The explanation is, of course, that the direction of Dorchester from Chelmsford is almost exactly the same as that of Rio. Other stations at Dorchester do not give the true bearing of Dorchester; for example, GLH and GLG working to New York both give approximately the New York bearing, GLL working to Cairo gives the Cairo bearing, etc. The explanation of these results, at first puzzling, is now clear. The direct rays from the beam stations are so weak as to be negligible. The rays received at Broomfield are those scattered back from the regions where the main transmitted beam penetrates into the scattering regions of the Heaviside layer. The case bears resemblance to that of a searchlight playing upon the clouds. Where the searchlight itself is hidden the point of intersection of the searchlight beam and the scattering or reflecting clouds appears to be the source.

Incidentally, these results show the existence of a very well defined beam, and direction finding observations are generally sufficient to determine whether any

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local transmitting station is a beam or not. By taking enough bearings to obtain a fairly well defined scattering direction, we can make a triangulation to determine the position of these scattering regions. The method cannot be very accurate, both because the base line is in general small compared with the distance of the scattering source, so that the triangle is very acute-angled, and because slight errors in the base angles make large differences in the actual distance. The inherent difficulty is the same as that experienced in obtaining the parallax of very distant stars, enhanced by the fact that accurate bearings cannot be obtained. To give an idea of the definition of the scattered bearings and to dispel the notion that these are too indefinite to base any conclusions upon, the records shown in Figs. 5 and 6 are given. The plate current from the amplifier was put through a recording

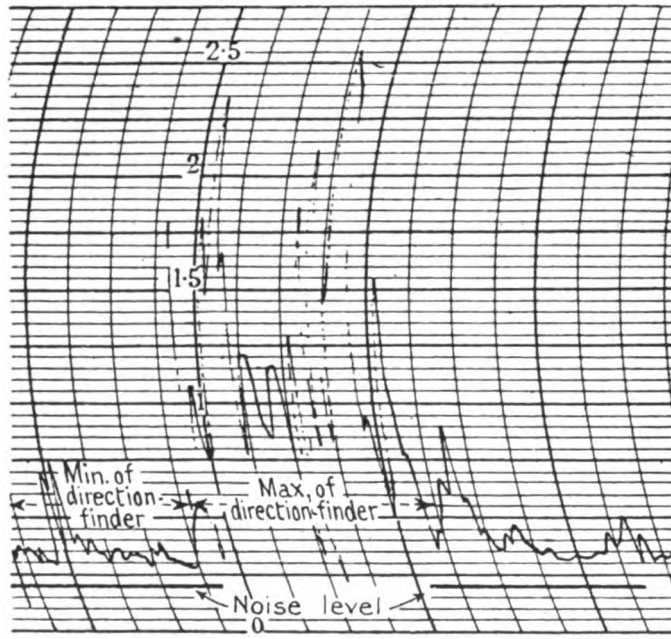

FIG. 6.—*Scattered signal from Station GBK.*

milliammeter and a record taken of the signals at the maximum and minimum positions of the goniometer. It will be seen that in the example shown the minimum signals are quite a small fraction of the maximum signals and a well defined direction can be obtained. Fig. 5 is an unscattered signal from WLL, while Fig. 6 is a scattered signal from GBK.

The results of the triangulations are shown in Table 1 and on the map (Fig. 4), which is more or less self-explanatory. The figures for the triangulation were furnished by the mean bearings during the 9 months in which regular bearings were taken of the local beam stations. They therefore give average results, and seasonal changes, if any, are obliterated. There were not enough observations each month to make it worth while taking separate means for these, and any variations would probably not be significant.

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The mean bearings were corrected in each case (especially for shorter waves), for the octantal error, which is known from the dimensions of the system. In obtaining the bearing of any transmitting beam A working to a station B we find, as described above, that the bearing of A is very nearly that of B. It is the difference between the bearings of A and B that is significant in the triangulation.

Where for any reason, *e.g.*, essential error in the goniometer, the bearing of B is in error by 2° or 3° or more, the bearing of A is corrected by this amount. This is essentially equivalent—except for the sphericity of the triangle—to making the small angle at the apex of the triangle equal to the observed difference of bearing of A and B. This, the author thinks, is the most accurate method where these small differences are concerned.

TABLE I.

Call Sign	Route	Wave-length	Delay	Distance of Scattering Source	
		m.	sec.	km.	
FW	Paris to Buenos Aires ..	14·6	0·0095	1,423	
GBJ	Bodmin to South Africa ..	16·15	0·0144	2,163	
GBI	Grimsby to India	16·2	0·0130	1,945	
GLH	Dorchester to New York ..	22·1	0·0144	2,166	
GBH	Grimsby to Australia ..	26	0·0150	2,260	
GBK	Bodmin to Canada ..	32·6	0·0131	1,967	
GBJ	Bodmin to South Africa ..	34·2	0·0895	1,341	Night
GBI	Grimsby to India	34·3	0·0144	2,163	
GLL	Dorchester to Cairo ..	21·85	0·0296?	4,440	Scanty result

The results in Table I, though rather few in number, show on the whole (except for GBJ working South Africa on the longer wave at night, and for GLL working Cairo, for which the observations are few) a remarkable consistency, being mostly in the neighbourhood of 2,000 km., although FW is rather smaller.

The scattered ray in general has to travel nearly 4,000 km. further than the direct ray (if it exists). This would mean a delay of the order of 0·0133 sec. It is hardly necessary to emphasise how well this agrees with the delay of short-wave echoes observed by Taylor and Young,* etc., and in the later part of the paper there is further evidence confirming this figure.

It is obvious from these results that quite an appreciable amount of energy is scattered back from distances of about 2,000 km.—rather a remarkable result. The significance of these observations in explaining the scattered bearings from broadcasting stations is clear (broadcasting used in the general sense as being non-directional). It seems in particular that all regions of the layer are equally or nearly equally capable of scattering energy. The echo and direction finding results are not, in fact, due to reflection from some particular region of discontinuity in the Heaviside layer, as has been suggested by some writers. A broadcasting station will scatter energy uniformly or nearly uniformly all round the receiver.

The interpretation of the balance aerial experiments and other direction finding experiments on broadcast transmissions which gave no apparent bearings is com-

* "Proceedings of the Institute of Radio Engineers," 1928, Vol. 16, p. 561.

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pletely confirmed. Observations of broadcast stations will, however, disclose any lack of uniformity in scattering if this exists in any marked degree, and the Dutch stations have given illustrations of this effect, but the beam bearings seem to show the existence of scattering in *some* degree *in all directions.*

The Balanced Frame and Vertical Aerial, giving a cardioid diagram, give a very clear indication of scattering.

The arrangement consists of a frame coupled to the receiver and a vertical aerial coupled to the frame aerial with a variable coupling M but not directly coupled to the receiver.

With an ordinary unscattered signal the E.M.F. in the vertical aerial can be made to balance that in the frame with suitable coupling M and phasing of the currents in the vertical aerial, and position of the frame, but under scattering conditions, say in the skip distance, the conditions are quite different, for it is observed that no balance position can be found and that the signal is a minimum when M is zero, *i.e.*, when the vertical aerial contributes nothing to the E.M.F.

The physical reason for this behaviour of the cardioid receiver can be expressed in a few words, if we assume that the received energy is scattered. The *energies* received by the aerial and frame are in this case added independently of phase, and there is always more energy when the two are coupled than when M is zero. Hence the minimum when M is zero. It seems impossible to explain these observations except in terms of scattering and we may consider them as another proof of the existence of scattering.

Multiplicity of Signals.

Short Echoes, etc.—It has been tacitly assumed that there are a large number of rays arriving simultaneously (or nearly simultaneously) at the receiver, when the signals are scattered. This, of course, implies multiple paths, and since these are not necessarily of the same length we should expect delayed signals and in extreme cases separate echoes. For this study the method of recording signals is undoubtedly the most fertile. Although we have not yet made a special study by this method, so much has been published that there is plenty of material to consider in the light of our scattering results. The two studies are complementary and neither alone tells the complete story. A casual study of the results obtained by E. Quäck,* Hoyt Taylor and Young,† Breit and Tuve, Tuve and O. Dahl,‡ Breit, Tuve and O. Dahl,§ R. A. Heising,‖ Hoag and Andrew,¶ undoubtedly furnishes examples of multiple signals, but usually two, three or possibly four multiple paths, and not the large number of paths which our observations on local beams imply. It may, therefore, be well to reconsider the question in the light of these echo results, and to attempt a reconciliation. Consider at the outset the effect of two or three rays exhibited by the records of echo signals. Thus, for instance, two signals 90° out of phase and perpendicular to each other in the horizontal plane will produce a rotating field in the goniometer with no indication of direction, but this is only if the two signals are equal. If the phases were not 90° apart, a more or less well-

* E. Quäck: *Zeitschrift für Hochfrequenztechnik*, 1926, Vol. 28, p. 177.
† A. Hoyt Taylor and C. J. Young: *loc. cit.*
‡ M. A. Tuve and O. Dahl: *Proceedings of the Institute of Radio Engineers*, 1928, Vol. 16, p. 794.
§ G. Breit, M.A. Tuve and O. Dahl: *ibid.*, 1928, Vol. 16, p. 1230.
‖ R. A. Heising: *ibid.*, 1928, Vol. 16, p. 75.
¶ J. B. Hoag and V. J. Andrew: *ibid.*, 1928, Vol. 16, p. 1368.

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defined bearing would be obtained. The direction finding results might be interpreted in this manner, but the probability that all the many hundreds of observed cases of no bearing are carefully arranged as above is negligible. As possibly the only alternative, we must conclude that each of the signals recorded is more or less composite when received in scattering regions, *e.g.*, skip distance, and it must be remembered that a recorded dot, for instance, bears no internal evidence of its composition.

A composite dot will consist of a number of separate contributions each of the shape of a dot, having between the elements time intervals depending on the difference of path length. The effect will be to broaden the dot and possibly to blur the start and finish. As a rule, unless the record of the received dot is compared with the record of the original there is nothing, except possibly the blurring, to show whether it has been broadened. There are, however, cases where, in effect, a broadened signal can be compared with the original. In certain cases there will be an echo which has traversed the globe, together with the direct signal. In such cases the echo signal will be but slightly scattered. These echo signals will always give good bearings, while the local dot will, in general, be scattered and composite, and therefore broadened. An example of this is shown in the records taken by Quack, where the initial signals in practically every case shown are of greater duration than in the echoes.

This effect was referred to in the author's previous short-wave paper, but the explanation did not occur to him until later. From the difference in length of the direct and echo signal we can get an estimate of the extreme difference in path between the elements of the composite scattered signal. Thus, in the case of the 15 metre station (AGA) at Nauen, received at Geltow, the initial dot is between 0·0129 and 0·0098 sec. longer than the echo signal. The end of the latter is not very well marked, hence the uncertainty. This corresponds to an extreme difference in path of between 2,940 and 3,600 km., and is in rough agreement with the figures arrived at by triangulating the source of the beam scattering.

Even the signals from 2XT (New York, $\lambda = 15$ metres) are slightly broadened in the short path as compared with the echo, there being a difference of time of 0·00444 sec., corresponding to a path difference of 1,332 km. With the correct set of conditions one might expect the short duration pulse signals used by Breit and Tuve and others to show a broadening. R. A. Heising has mentioned cases of these, but attributes them to movements of the layer. The blurring effect at the beginning and end of signals is shown in the records taken by Hoag and Andrew, in particular the wedge-shaped distortion labelled " B " in his type figure.

The experiments described here seem to put the existence of scattering beyond doubt, but as to the cause of this scattering only conjectures can be made. It seems clear in any case that the Heaviside layer must consist of patchwork structure of ionic clouds.

The mesh of this structure must be large compared with the wavelengths considered, and it seems probable from physical considerations of diffusion that the scattering layer cannot be much higher than 120 to 130 km. The existence of such scattering makes the theory of short-wave transmission, which is already complex enough, even more so, but in considering the usual ray theory, the existence of scattering will have to be taken into account before a complete theory can be formulated.

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A WIRELESS BEACON CABINET TRANSMITTER

TYPE W.B.2

The use of an automatically operated Wireless Transmitter situated on land and sending a code signal is unquestionably of great use for marine navigational purposes.

With the Marconi set to be described below, which is entirely self-operating with the exception of the manual winding of the clocks, only about ten minutes' attention is necessary once a week, with an occasional overhaul at protracted periods.

Such a transmitter is especially useful in times of fog, when the signal which is generally sent only a few times every hour, can be continuously transmitted.

THE Type W.B.2 Beacon Transmitter is designed in as simple a manner as possible to give the most efficient and constant automatic service that could possibly be desired in a set of this type.

The complete installation includes :—

1. The transmitter.
2. One clock switchboard.
3. Two Venner time clocks.
4. Two character wheels.
5. One A.C. switchboard.
6. Two 750 watt motor alternators.
7. Complete automatic charging plant and battery.

Transmitter.

The transmitter is designed to take a total input of 750 watts, and to operate on I.C.W. only. Consequently no smoothing system is provided. A diagram of connections of the transmitter is shown below. It will be seen from this that a system of double wave oscillation is employed. That is to say that each of the two valves employed only oscillates on that part of the input voltage which is positive with respect to its filament. This may be shown more clearly in Fig. 1, where the anode circuits of each valve are shown simplified.

It will be seen that the secondary of the power transformer has its mid point earthed, and this point will always be at a node of potential. The set is keyed from the primary of the power transformer.

The aerial is tuned by means of inductance taps and a variometer, and is coupled to the closed circuit by means of a variable coupling coil. The closed circuit also consists of an inductance tuned by means of taps and a variometer. Reaction is

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applied to the grids of the oscillators by means of a variable coupling coil in this circuit. A simplified diagram of the oscillation circuit is shown below (Fig. 2). In this diagram only one of the two valves is shown, and the positive half of the wave is assumed to be impressed on the anode.

The waverange of the set is nominally from 950—1,050 metres, but it is usually desired to work on a spot wave in the vicinity of 1,000 metres.

TYPE W.B.2 TRANSMITTER.
The Iron-mesh front and side covers have been omitted for the sake of clearness.

The two valves used for the oscillator are duplicated, so that in all four valves are mounted in the set. If either of the filaments of the two valves in use burn out,

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the alternative valves are connected and the old ones disconnected by the action of a hot wire relay, which, besides changing the valves causes a loud speaker connected to a transformer in the filament circuit of the valves to hoot, thus warning the custodian of the set that the first set of valves needs replacing. The valves used in the transmitter are T.250's. The filaments of the valves are also lit by A.C. from a separate filament lighting transformer. Apart from the above facts and the general sturdy and foolproof construction of the transmitter no further details need be given of this part of the installation.

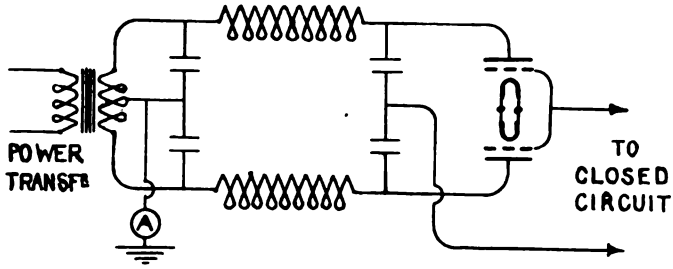

FIG. 1.

Action of the Transmitter.

As has been previously mentioned, this set is designed to send out pre-arranged signals at certain definite intervals of time. The whole installation is controlled and keyed by means of the Venner time clocks. Each of these clocks controls two sets of contacts. The first of these contacts on closing start one of the motor alternators and one of the character wheels. 45 seconds after the first contact has closed the second contact closes, and by engaging the clutch on the character wheel, keys the set.

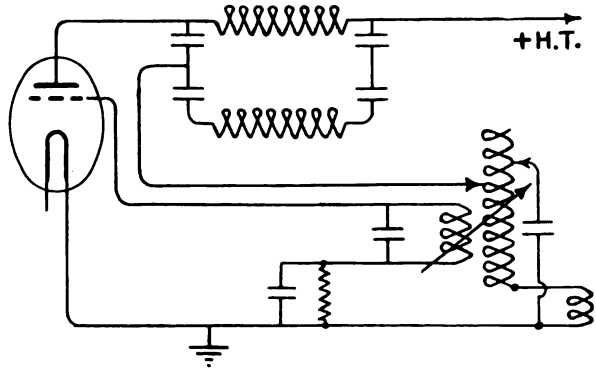

FIG. 2.

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Two double throw switches on the switchboard are provided for changing the clocks and character wheels. A tumbler switch marked FOG/FINE enables a continuous series of signals to be sent in foggy weather. This is accomplished by shorting two contacts of the clock switch, thus rendering the No. 1 contacts of the clock inoperative and allowing the No. 2 contacts to key the set as in the FINE position.

A dimming resistance in series with the secondary of the lighting transformer allows the valves to be run with dim filaments when the set is on space. On mark the No. 2 contacts of the character wheel short this resistance, thus bringing the filaments of the valves up to their normal brilliancy.

In this way the life of the valves is considerably lengthened.

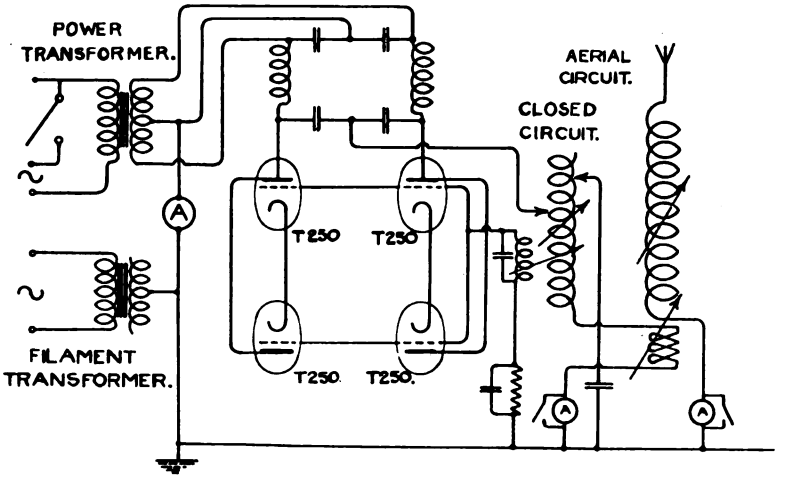

FIG. 3.

A simplified diagram of connections of the transmitter is shown in Fig. 3.

Character Wheel.

The character wheel consists essentially of a steel wheel on which certain projecting portions are cut corresponding to the signal that is desired. This wheel is driven from a worm drive from an electric motor. The wheel is normally separated from the drive by means of a clutch which is pulled in by means of a 50 volt solenoid provided with an economy resistance. The code wheel is provided with three contacts, whose functions are as follows :—

No. 1. Operated by code wheel itself and used to key the set.

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No. 2. Used to operate the dash signal, which is normally of 10 seconds' duration.

No. 3. Closes shortly after the No. 2 contacts of the clock and connects two contacts in parallel with these No. 2 contacts. Its function is to take the load off the No. 2 contacts of the clock after these have been closed for 45 seconds only.

Power Supply, etc.

The power supply for the set is derived from a 50 volt battery of accumulators. These are charged from one of two Crossley engines. A master switchboard controls the whole of the charging and discharging arrangements. This switchboard is provided with a series of relays which cut in extra cells as the voltage of those in use drops; and when the cells are discharged, automatically starts one of the engines and arranges for the charge to be continued until the battery is completely charged again. The two engines are started alternately so that equal wear is given to both.

WIRELESS RECEIVING SETS

Marconi Company's Licence Upheld in Courts of Justice.

At the moment of going to Press, June 18th, two important decisions in favour of Marconi's Wireless Telegraph Co., Ltd., were given by Mr. Justice Luxmoore in the British High Court of Justice.

These judgments concerned the granting of licences to manufacturers under the wireless broadcast and valve patents controlled by the Marconi Company, and reversed decisions given in a Lower Court by the Comptroller of Patents, who granted compulsory licences in favour of the two manufacturing companies concerned.

In the first case, the Brownie Wireless Co. of Great Britain, Ltd., desired to commence the manufacture of valve receivers, but objected to the form of licence offered to them. They alleged that such licence would be injurious to their business, and was an abuse of the Marconi Company's monopoly rights, and they, therefore, asked the Comptroller to grant them special terms under particular patents in order to enable them to produce cheap wireless sets. The licence offered by the Marconi Company was the general form of licence granted by that Company to the majority of their licensees, who numbered at the time of the application over 2,000.

The Judge reversed the decision of the Comptroller of Patents, who had granted a licence in the terms asked, and held that the main conditions of the Marconi standard licence were reasonable. He held that no evidence had been brought to show that there was any dissatisfaction in the general wireless trade with this form of licence, or that there had been an abuse of monopoly rights, or that the Brownie Company were entitled to a different form of licence. The Brownie Company's application therefore failed, and the Comptroller's decision was discharged with costs.

The second case concerned an application by the Loewe Radio Co., Ltd., for a licence to manufacture multiple valves in Great Britain. Before proceeding with the manufacture of these valves under Loewe patents it was necessary for the Loewe Company to obtain a licence under the Marconi Company's broadcast and valve patents.

The Loewe Radio Company applied to the Marconi Company for a licence under certain patents. After negotiations had proceeded for some time the Loewe Company decided to apply to the Comptroller-General of Patents for a licence on terms which differed materially from those offered by the Marconi Company's standard agreement. The object of this proceeding was to enable them to manufacture their valves in England more cheaply, and thus reach a larger public. The Comptroller of Patents decided in favour of the Loewe Company's application, and granted a compulsory licence.

The Judge, on appeal, decided that no case had been made out for the granting of such a compulsory licence, and discharged the Comptroller's decision. The Judge expressed the opinion, however, that some form of licence should be agreed between the parties, and intimated what, in his opinion, should be some of the main conditions of that licence.

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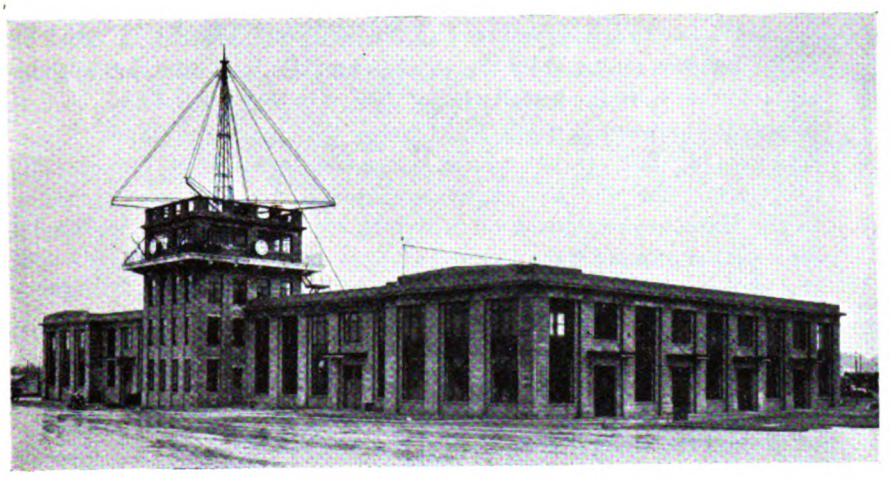
MARCONI NEWS AND NOTES

AIRCRAFT WIRELESS

VALUE OF WIRELESS DIRECTION FINDER IN FOG



London Air Port, showing Control Tower and Direction Finding Aerials.

THE use of wireless direction finding for navigation on the airways has become so much a part of the normal organisation that it hardly excites notice to-day, except when some notable achievement brings it to public attention.

Such an instance occurred on March 26th when the Prince of Wales flew from France to England. There was a dense fog over the Channel, but so experienced are the Airways pilots in making the journey in fog, with the aid of the Marconi Wireless Direction Finder, that there was no hesitation in making the trip with the Prince.

Describing the flight in an interview with a London newspaper, Captain O. P. Jones, of Imperial Airways, who was the pilot, said :—

> "We saw nothing but the floor of the cloud-tops beneath us from half-an-hour after leaving Le Bourget until we arrived at Croydon, but . . . with a multiple-engine machine and wireless direction finding, the risk of having to make a forced landing is negligible."

The London Air Port and all Imperial Airways passenger machines are equipped with Marconi Wireless apparatus. It is also used in over 30 other countries.

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Other instances of the use of the Direction Finder.

The following letter, which has been received by the Marconi Company from the Société Anonyme Belge d'Exploitation de la Navigation Aérienne, is a further tribute to the excellence of Marconi aircraft wireless and direction finding apparatus, and to its value in aerial navigation :—

> " We beg to advise you that all the pilots of S.A.B.E.N.A. are delighted at the services rendered by the wireless and the land direction finding sets, and it is thanks to the installation of these sets that the S.A.B.E.N.A. is able to operate between Brussels and London with such well known regularity. As a case in point, on the occasion of the last voyage of M. Lippens, Minister of Aviation, our pilot M. Cocquyt was able, thanks to direction-finding and to the Marconi installation on board, to effect the flight above the clouds, for a period of more than 2 hours, without any land observation other than the radiogoniometric observations transmitted by wireless."

Instances of this kind are constantly being reported to the Marconi Company, and it will be remembered that Captain Wilcockson and other well-known Imperial Airways pilots have flown from Paris to Croydon in foggy weather with hardly a sight of the ground throughout the journey.

Captain Wilcockson's experience.

These circumstances show the degree to which the standard Marconi wireless apparatus used on Imperial Airways machines flying between Croydon and the Continent is relied upon, and Captain Wilcockson's experience in piloting a Handley Page Rolls Royce aeroplane from Paris to Croydon above a fog bank which obscured the ground practically the whole of the way, is worth recalling.

In spite of the denseness of the fog Captain Wilcockson completed his journey in 2 hours 26 minutes, which is a good average time for the trip from Paris to London. When he started from Le Bourget at 8 a.m. visibility was about 1,000 yards, and the weather report gave fog over most of the route except for patches of clear weather near the French coast and at Biggin Hill. Five minutes after leaving Paris Captain Wilcockson found himself in dense fog and had to rise 2,000 ft. to get above it. At this height the aeroplane was flying in bright sunshine and continued to do so for the greater part of the journey. It was, however, necessary to fly entirely by compass bearing. The pilot asked for several bearings and positions from Croydon during the journey and these brought him in on a direct line to the Croydon Aerodrome. There was one break in the fog, about 10 miles from Croydon, which enabled the pilot to recognise the ground and corroborate the fact that he was on the right bearing. The fog then closed in again and in his own words he " dropped right on the aerodrome."

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In an interview Captain Wilcockson said that this was one of the worst fogs he had ever experienced, but he had no doubt during the whole journey that he would get through in comfort as his past experience with his wireless apparatus had given him confidence that he could navigate on bearings through the fog, however dense it might be. " I had no difficulty at all in keeping in communication with Croydon at any time, whether I was in the fog, above it, or when coming down to the aerodrome, but it would have been impossible to have made the journey without wireless" Captain Wilcockson said. " The apparatus I was using was the ordinary A.D.6 apparatus and not any new or special apparatus."

There were five passengers on the machine. They had a very happy and comfortable journey and were quite thrilled with their novel experience.

Handicapped by lack of Wireless.

An instance of the handicap from which pilots suffer when they do not carry wireless on long distance flights was provided during the flight of Flight Lieutenant Moir and Flying Officer Owen of the Australian Air Force, from England to Australia. After taking off from the Isle of Sumbawa in the Dutch East Indies on May 17th no news of them was heard for ten days until, after diligent search, they were found by another flying officer near the Cape Don Lighthouse, Northern Australia.

As the *London Times* remarks in a leading article, " the only clear lesson of the adventure so far is the old lesson that machines for long and adventurous flights should carry wireless and be provisioned and equipped to meet emergencies." " Wireless," *The Times* said, " also appears indispensable for lighthouses like the Don, situated on coasts far from the aids of civilisation."

The Excellence of G5SW.

In the South African *Merry-go-Round* of May 15th appears a striking tribute to the efficiency of the London Experimental Short Wave broadcasting station—G5SW—which is operated at Chelmsford by the Marconi Company for the British Broadcasting Corporation. This station is described as the " star " station for South African listeners.

The writer in the *Merry-go-Round* continues :—

> " This station is experimenting with two types of aerials and reports are requested. Announcements regarding times of tests are put over at 10, immediately after the time signal. Antenna A is as perfect as I expect they will ever get it. The old complaints *re* wobbly note, poor signal strength and too many talks have all vanished, and instead we have a dead steady note with small loud speaker strength, and few or no talks after 9 o'clock. It is a real pleasure to listen to this station, and everyone I meet has nothing but praise for G5SW."

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Marconi Installations for Entertainment at Sea.

A new Marconi installation, which is likely to have a wide appeal, was used for the first time on May 23rd, on board the "Crested Eagle," a pleasure steamer, belonging to the General Steam Navigation Company, voyaging between London, Margate and Ramsgate.

On board the "Crested Eagle."

The installation consisted of a central microphone and loud speakers, at various points, by means of which passengers were entertained, throughout the journey, by music and a description of the places of interest on the coast.

While the programme could be heard in comfort by passengers in nearly all parts of the ship, one part of the ship was reserved for passengers who preferred to sit in quietness. The installation was so arranged that loud speakers could be plugged in or disconnected at any point according to whether or not they were required.

At a luncheon given on board the "Crested Eagle" Mr. Stanley Sparkes, a Director of the Company, said the General Steam Navigation Company intended, with the aid of the Marconi Company, to make the journey more interesting by descriptions and information regarding places seen from the ship and by musical entertainment.

The accompanying photograph gives a view of the "Crested Eagle" and the passengers enjoying the broadcast music and descriptions during the voyage.

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No. 10

THE MARCONI REVIEW

July, 1929

CONTENTS

A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS—II - - - - - - - PAGE 1

X.M.C.2 COMBINED TRANSMITTER AND RECEIVER - - - - - - - „ 11

THE DESIGN OF WAVE FILTERS - - - „ 15

MARCONI NEWS AND NOTES—

THE MARCHESE MARCONI - - - „ 26
BEAM WIRELESS FOR BROADCASTING - „ 26
TELEPHONY BY BEAM - - - - „ 28
THE VATICAN WIRELESS STATION - - „ 28
INTERNATIONAL LIGHTHOUSE CONFERENCE „ 28
WIRELESS ON TRAWLERS - - - „ 31

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD.

Marconi House, Strand, London, W.C. 2

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THE MARCONI REVIEW

No. 10. *July, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS

PART II.—SOME USES OF THE SYNTHESIS MODEL, IN PARTICULAR THOSE RELATING TO WIRELESS PRACTICE

A description of a mechanical model designed by the Author for use at the Marconi College, to enable wave synthesis to be carried out easily was described in the June issue of THE MARCONI REVIEW, *and it was there mentioned that this would be followed by a second part in which the uses to which the model could be put would be described.*

This second part has for convenience been divided into sections, the first of which is given below.

Section 1—The Modulation of High Frequency Waves and the Relationship of Carriers to Side Bands.

WIRELESS practice concerns the art of communication using æther waves and comes under the heading of a signalling system.

Signalling systems in general are usually associated with the transmission and reception of waveforms of audio frequency, and we can assume that we are concerned in signalling frequencies from a few cycles up to 10,000, this band width being encountered in the transmission and reception of broadcast music, which probably represents the most complicated form of signal. When transmitting hand speed morse this may be considered as the signalling of a square wave of a few cycles per second the frequency depending upon the speed of sending.

Speaking quite generally one may conceive any signalling system as having two essential features:—

1. The means of transferring energy from transmitter to receiver; in the case of ordinary speech between individuals this energy will consist of sound waves, in the case of land line working, current along conductors;

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and in the case of wireless the propagation of electro-magnetic waves through the aether, to mention a few methods.

2. The second part, integral with the first, and no less essential if signalling is to be carried out, is the Modulation, which is the means by which intelligence is conveyed. As its name implies, this is the moulding of the energy (the first part), and as before mentioned will take the form of some audio frequency wave.

Both parts are of course complementary, one to the other, but they can be separated for the purpose of analysis.

We may divide signalling systems in three classes :—

(A) Non-carrier systems.

(B) Carrier systems.

(C) Suppressed carrier systems.

A non-carrier system is one in which energy transference only appears with the signal.

If, however, transmitter and receiver are linked, even though no signal is being made, we have what is known as a genuine carrier system.

We may yet have another case where, although no carrier links transmitter and receiver, it originally existed but has been suppressed. In such a case it will be necessary to incorporate the equivalent of the carrier at the receiver, and such a system would be called a suppressed carrier system.

Wireless is essentially a carrier system, but before discussing the features of the wireless case it may be of interest to say something of carrier systems in general.

As previously mentioned, in any signalling system we are interested in the transmission and reception of intelligence usually in the form of a wave. Such a signal may be a simple harmonic wave or capable of division in harmonic components. In the latter case the signal may be considered as a spectrum of frequencies.

We can transmit a signal along a communication channel with the least expenditure of energy when the datum line of the signal wave coincides with the zero line of disturbance in the channel. For instance, suppose one wishes to transmit a sine signal along a line. The signal could be sent by a transmitter changing the current in the line, first in one direction and then in the opposite direction, requiring a certain minimum expenditure of energy and, when no signal is being made, there is no current in the line. Thus, we can say that the datum line of wave coincides with zero line of current in the system and it is to be observed that in this case a reversal of phase takes place at the half cycle of signal. Such is an example of a non-carrier

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system. This changing line current, that is the signal, could be detected by a suitably designed receiver.

The carrier case would be one in which a D.C. current of sufficient amount was permanently flowing in the line so that the introduction of the signal merely augmented and diminished the original current called the carrier current. Thus in the carrier case a current always flows in the same direction and the carrier now forms the datum line for the signal wave.

Such a D.C. carrier can be eliminated from the line by using transformers, and can be added locally at transmitter and receiver. In this case we get an example of suppressed carrier system. Examples of all these cases are shown in Figs. 1a, 1b, 1c and 1d, and from them we can make the following observations :—

1. The signal made depends only upon the modulating component disregarding any peculiarities of the receiver.
2. The carrier current contributes nothing to the communication of intelligence, but merely forms a datum line for the signal wave.
3. The use of a carrier involves an additional expenditure of energy which may be very considerable.

It may be worth while pointing out now, that we can only talk of percentage modulation when we are discussing carrier systems. What we mean when we say that a carrier system is so much per cent. modulated is that the amplitude of the modulating component is that much per cent. of the original carrier, one hundred per cent. modulation meaning, therefore, that the peak value of the modulating component is equal to the original carrier value. The effect of this is that at one period the disturbance in the system is reduced to zero, and at some other period is built up to a value equal to twice the original carrier.

A carrier system is obviously a wasteful one and it is necessary to state why one has sometimes to use carriers, and the explanation will, it is suggested, be found at the receiver. Comparing the two line cases, for instance, we see that in the non-carrier system, for the receiver to detect the signal it has to be capable of following not only change of amplitude of current, but change of direction as well. This means considerable intelligence on the part of the receiver. On the other hand, if a carrier system is being used the receiver has only to be able to detect change of amplitude and no change of phase comes into the matter. Thus, the real reason why a carrier may be required is because the receiving system has not sufficient intelligence to do without it. Of course, if one can improve the mentality of the receiver sufficiently one can do without carriers, and in the ordinary line system there are many examples of " high-brow " receivers which dispense with carrier currents and thereby save a considerable amount of energy.

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For instance, in the line telephone example given in Fig. 1a, where the receiver is unpolarised, it has only sufficient ability to understand change of amplitude and not change of direction. Hence, although the transmitter diaphragm flapping first in one direction and then in the other creates a reversed current in the line, this reversal of current does not means anything to the receiver and the signal appears distorted as shown.

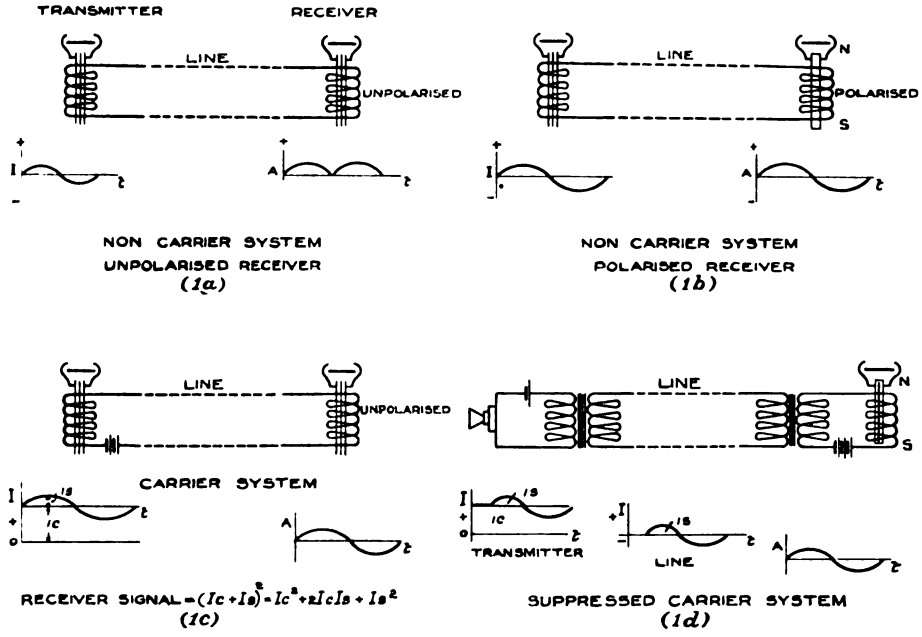

FIG. 1.

Fig. 1b shows a receiver with improved mentality, by polarisation with permanent flux, and in this case the reversal of current is now observed and correct reproduction results.

Had one of necessity to use the original type of receiver, the trouble could be overcome by adding a D.C. carrier as shown in Fig. 1c, although this carrier need not pass along the communication channel but could be localised to the receiver circuit as shown in Fig. 1d.

Wireless communication is essentially a carrier system for the same reason, that our receivers lack intelligence and because high frequencies are necessary for the transmission of the wave. Instead of a D.C. carrier we have an A.C. carrier creating an image wave, and because of this image wave, to demodulate, rectification

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is essential at the receiver. From which one can observe that since at the receiver the datum line of signal wave is above zero line of disturbance, we must have a carrier, at the receiver.

It is of interest to consider the relation of this A.C. carrier to the modulating component, and to discuss the possibilities of carrier suppression.

Up to the present time modulation of a high frequency carrier has been almost exclusively an amplitude modulation and there are two ways of visualising the effect of amplitude modulation on a carrier. The first is that the modulating component alters the amplitude of the carrier so that the envelope produced conforms to the signal required. In this case we conceive the original carrier merely being varied in amplitude in accordance with the signal wave. This method of visualising a modulated wave is quite helpful until one talks of Suppressed Carrier Systems and commences to analyse the distribution of power in carrier and modulating component, when it becomes rather involved.

But it is well known that one can analyse such a modulated wave into a spectrum of waves consisting of the original carrier and two sets of side bands.

It is not proposed to go into the spectrum analysis fully but merely to set out such features as may be necessary for discussion.

A signal wave may be analysed into a series of harmonic waves of definite frequencies and amplitudes and having set phases, and these plotted as a frequency amplitude spectrum, can be shewn diagramatically thus :—

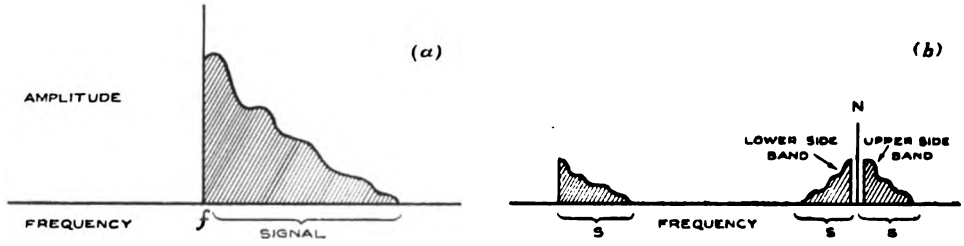

FIG. 2.

The actual width of the spectrum and the amplitudes of the different harmonics is dependent upon the character of the signal wave, and in practice (excluding television) music gives the widest spectrum and may cover a band of as much as 10,000 cycles.

The effect of modulating a high frequency carrier of, say, frequency n by such a signal, may be considered as producing a high frequency spectrum which is obtained

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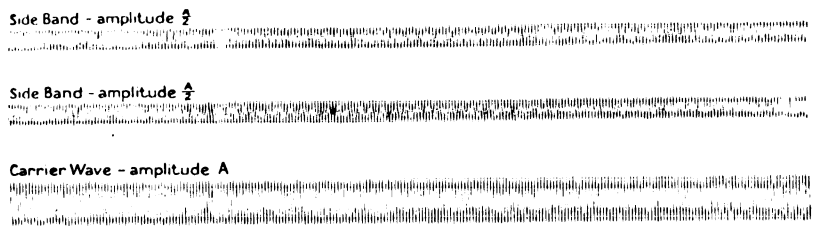


FIG. 3.

2A MODULATION - 100% CONTROL (K=1)

Modulation of carrier wave by pure tone signal

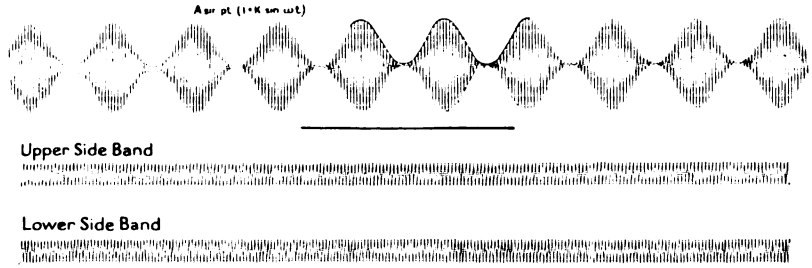
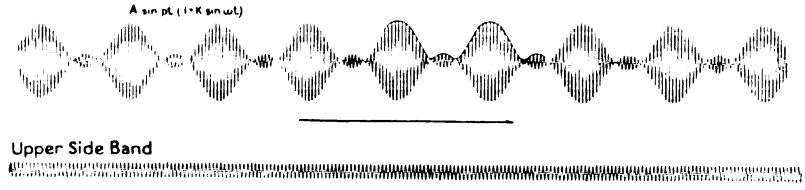


FIG. 4.

2B MODULATION - OVER CONTROL - (K=1·25)

Illustrating conditions which would give rise to distortion in Radio Telephony.



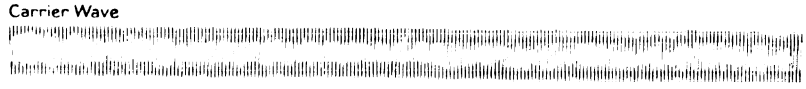


FIG. 5.

2C MODULATION-UNDER CONTROL (K=0·5)

Illustrating modulation conditions consistent with good quality.

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by moving the signal wave along the frequency base by the amount of the H.F. carrier. In addition to this a reversed image spectrum is created on the lower side of the carrier as is shown in Fig. 2B, from which it can be seen that the high frequency spectrum is roughly twice the width of the signal band.

This high frequency spectrum thus consists of the following essential parts :—

1. The original carrier.
2. A band of H.F. waves obtained by the sum of carrier and signal frequencies, called the upper side band.
3. A band of H.F. waves obtained by taking the difference of the carrier and signal waves, called the lower side band.

The amplitudes of the side band waves depend upon the degree of modulation, and the power required to produce these side band waves represents the additional power necessary to effect modulation of the carrier.

To modulate one has to do work—one can either think of the work being expended in producing an alteration in the amplitude of the original carrier, or as producing an additional spectrum of high frequencies which, beating with the original carrier, produce the synthesis wave whose envelope after demodulation will conform to the desired signal, and for the correct reproduction of envelope all the components of this spectrum are required.

It is observed that only parts 2 and 3 introduced by modulation convey intelligence. Further, that the band width taken up is dependent upon the signal spectrum and is therefore independent of the frequency of communication.

It is of considerable interest to study the distribution of power in such a built up wave and to observe the effects of phase displacements. The simplest case of all is modulation of a carrier by a pure sine signal, producing a synthesis wave which can be expressed :—

$$Ft = A \sin pt\,(1 + K \sin \omega t) \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where A is the amplitude of carrier

p = 2π times carrier frequency (n)

K = factor of modulation being 1 for 100 per cent.

ω = 2π times signal frequency (f)

The expansion of the above gives us the separate carrier and side bands as

$$Ft = A \sin pt + \frac{KA}{2} \cos (p - \omega)t - \frac{KA}{2} \cos (p + \omega)t \quad \ldots\ldots \quad (2)$$

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Thus if the carrier amplitude is 1, then for 100 per cent. modulation, each side band amplitude will be one half the carrier.

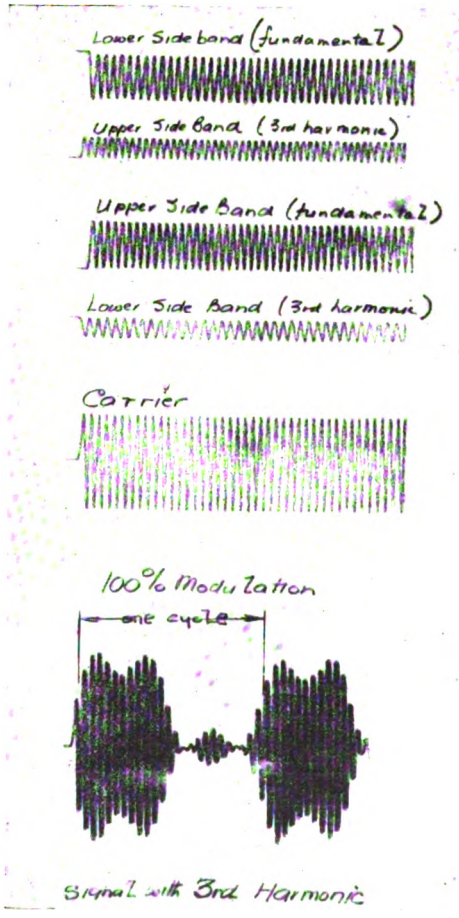

FIG. 6.

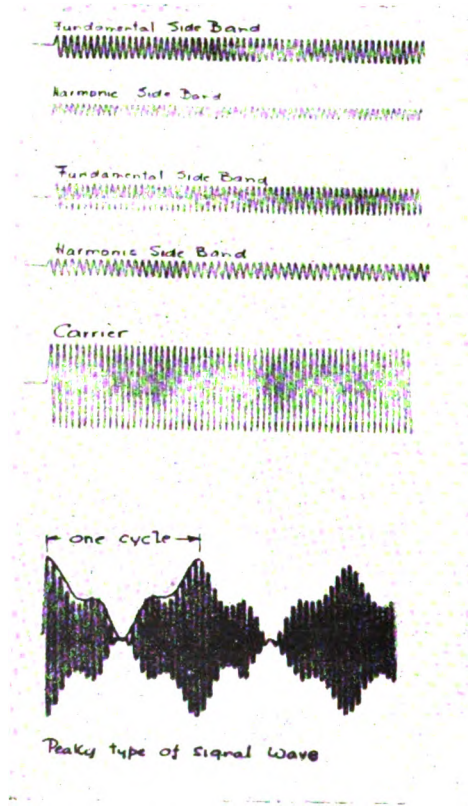

FIG. 7.

To demonstrate a sine modulated carrier the machine is set up to accord with the mathematical expression, and in the examples shown the carrier frequency is 25. With a modulation frequency of 1, two side band frequencies of 26 and 24 will be produced, each of amplitude half the carrier, for 100 per cent. modulation.

The result of the addition of such a spectrum is shown in Fig. 3, the frequencies being carefully set not only as regards amplitude but also as regards phase.

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In order to obtain exactly correct frequencies it is necessary to have a very fine adjustment of frequency for the carrier wave. This is accomplished by employing for the final carrier drive two opposed cone pulleys, each having a coning of $\frac{1}{16}$in. in 2in. width, so that by sliding a flat belt across the faces of these pulleys an exact frequency can be obtained. With such an arrangement, even after some 200 cycles, the three frequencies are still found to be substantially correct. It is observed that an accuracy of something like 1 part in 15,000 is obtained in this way.

The distribution of power in such a modulated wave will be proportional to the square of the individual waves, and it will be seen that in the above case there will be twice as much power in the carrier as there is in the two side bands together, *i.e.*, for the case of a sine signal. If we have a carrier 50 per cent. modulated, shown in Fig. 4, which is a more normal case for a broadcast set, then the amplitude of each side band will be a quarter the carrier amplitude for a sine signal, and hence the power in both side bands is only one-eighth of the carrier power.

If one modulates too deeply, side band power is produced in too great a proportion and the result is a distorted wave as shown in Fig. 5 where the signal impressed is a sine wave and the modulation 125 per cent.

The power proportion of carrier to side bands is, of course, not a constant for a given percentage modulation, but varies with the type of signal wave, the more peaky the wave form the less power required to produce it, for a given value of peak amplitude. It really comes to a question of wave area. This is shown in examples on Figs. 6 and 7. Fig. 6 shows a carrier modulated by a signal wave having a third harmonic with such a phase that the harmonic does not raise the peak of the wave but merely broadens it. In the case of such a signal having one harmonic, there will be two side band waves each side of the carrier, one pair for the fundamental and one pair for the harmonic as shown. Thus, for 100 per cent. modulation a fundamental signal amplitude of half the carrier can still be retained without over modulating, and the amplitude of carrier, fundamental side bands and harmonic side bands will then become as shown, *i.e.*, the fundamental side bands are half the amplitude of the carrier, and the side bands produced by the signal harmonic are one-sixth the amplitude of the carrier. The power distribution in such a wave will be 1 in carrier to ·555 in side bands, showing that because the wave is broader for the same peak value its power content is greater than in the sine case. Had the third harmonic been included such that it came in phase with the peak of the fundamental wave thus making the envelope peaky, with the same carrier (as shown in Fig. 7), it would be necessary to reduce the amplitude of the signal component to prevent over modulation. In this case each fundamental side band would need to be reduced to ·375 and each harmonic side band to ·125. The power content of the two side bands then becomes ·312 of the power of the carrier for

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100 per cent. modulation. As it is usually necessary to allow for peaky type waves, the average level of modulation must be considerably lower than that calculated for the sine case.

Incidentally in the two cases just given (Figs. 6 and 7), if such waves were rectified and passed through a telephone, the effect on the ear would be the same although the strength of 6 would be a little greater than that given by 7. This point will be referred to later.

The type of modulation requiring the most power is a square wave, as it has the greatest area for a given maximum amplitude, and in this case the power in the side bands rises to equal that of the carrier, for 100 per cent. modulation. Thus, given the most favourable conditions there will always be as much power expended in the carrier as there is in the side bands, and usually the distribution of power is very much less favourable. When one considers the small amount of power that is used on the average to modulate a carrier it would appear that present systems are very inefficient.

In choke control, for instance, under the most efficient conditions for the modulator (50 per cent.), we use twice as much power as we are ever likely to be called upon to provide, *i.e.*, for a square wave, and under normal working conditions it is problematical whether the average useful power delivered from the modulator exceeds one-tenth of the carrier power.

Another point is the interference question. The " figure of merit " of a signal is not so much its strength as the ratio of its strength to interference. This ratio will be improved if all the transmitted power is put into the side bands instead of using a large proportion in a carrier. Apart from the waste of power in the transmitted carrier, the present carrier and double side band working is a bad one because of the width of frequency band taken up, and in view of the ever growing crowding of stations it would appear that in the future some alteration in the modulation system must come about, where possible, so that the number of channels can be increased.

The foregoing is sufficient to show how uneconomic the present carrier system is, and it may be of interest to discuss the effect of carrier suppression. Because we are dealing with a spectrum of alternating current waves this involves a knowledge of the effects of phase relationship of the waves making up the band, and it is proposed to study this in detail in the next Section of the paper.

A. W. LADNER.

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X.M.C.2 COMBINED TRANSMITTER AND RECEIVER

The most important conditions of service to be met by a set of the type of the X.M.C.2, which is primarily designed for installation on whalers, trawlers, tugs and lightships, etc., for intership and ship to shore communication, are as follows :—

1. *The apparatus must be capable of adjustment and operation by absolutely unskilled personnel.*
2. *The instruments will be installed in remote places far removed from any facilities for repair or expert advice.*
3. *The installation will be subject to extreme climatic conditions as regards temperature and humidity, and will be mounted, in general, in very confined spaces.*

Adequate provision is made in the design of the X.M.C.2 to meet these exacting conditions, and, as numerous good reports of its performance have been received, the description of the set given below may be found to be of general interest.

THE X.M.C.2 transmitter and receiver have been designed to permit intership and ship to shore communication to take place on any spot wave between 150 and 450 metres, using either telephony, interrupted continuous wave or continuous wave.

Power Supply.

The power supply to the transmitter is intended to be taken from the ship's mains, which are used to drive a motor generator, the motor of which is wound to suit the mains, and the generator to provide a high tension voltage of 2,500 volts for the anodes of the valves and a low tension voltage sufficient to charge the filament battery at the full rate when on the charge position, and at one-third the full rate when on the transmit position in addition to supplying the filament current for the valves.

A motor field regulator, H.T. generator field regulator, and L.T. generator field regulator are provided and are mounted on the motor generator unit.

Power of Transmitter.

The power of the transmitter is rated at 0·5 kilowatt from the output terminals of the generator. The total power to the anodes of the two transmitting valves is 438 watts.

Transmitter.

A simplified diagram of connections of the X.M.C.2 transmitter is given below

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(Fig. 1). It will be seen from this that two valves are used, namely, an oscillator and a modulator. Marconi valves, type M.T.12a, are used in both cases. The aerial circuit consists of an inductance which is tuned by a variometer and tappings on the coil itself. Variably coupled to the aerial inductance is a coil, one end of which is earthed and the other end is taken to a tap on the closed circuit inductance. This latter is

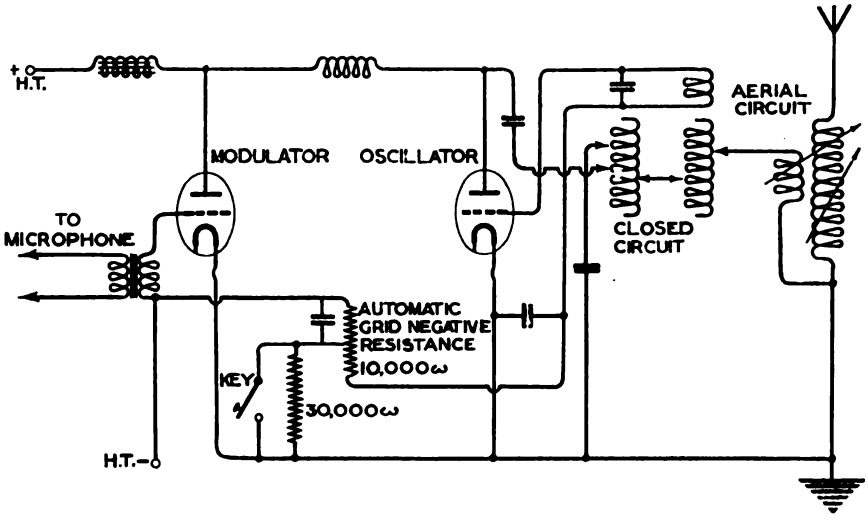

FIG. 1.

also tuned by means of a variometer, and an adjustable tap. Three tappings are taken from this closed circuit coil. One is taken to earth through the closed circuit condenser the value of which can be changed according to the wavelength required. One is taken to the anode of the oscillator through a condenser, and one is taken to the aerial coupling coil as has been previously mentioned. A variable reaction coil, shunted by a condenser, is connected between the grid of the oscillator and grid negative. When transmitting on C.W. the grid of the oscillator valve, which is permanently connected to negative H.T., is disconnected or connected to earth by means of the transmitting key.

Modulation on telephony is accomplished by the choke control system. The anodes of the modulator and the oscillator are connected by a high frequency choke, and the H.T. supply to both the anodes is taken through an iron core choke. The high frequency choke is provided in the circuit to prevent the plate circuit of the modulator taking any of the high frequency power which the oscillator should be supplying to the aerial circuit. The action of the iron core choke is to present a high impedance to audio frequency currents, and to give the greatest variations of modulating voltage on the plate of the oscillator.

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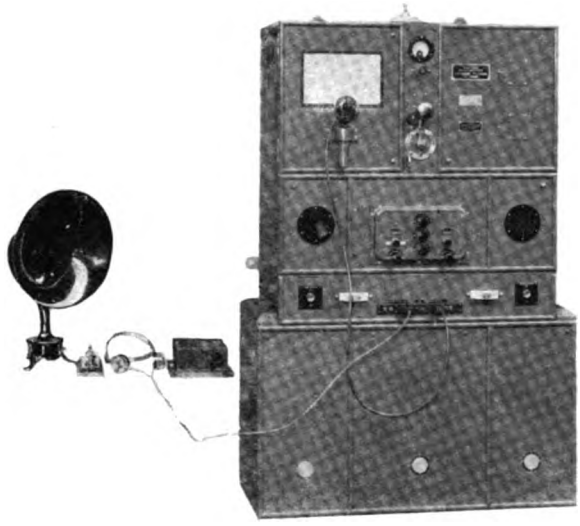
When transmitting on I.C.W. a buzzer which is in series with a third winding of the microphone transformer is keyed and impresses this voltage which is at the frequency of the buzzer on the grid of the modulator.



Receiver.

The X.M.C.2 receiver is designed to receive on all wavelengths of from 150—600 metres, and these wavelengths are covered in two ranges.

A diagram of connections is shown below (Fig. 2), and it will be seen from this that four valves are used in the receiver, the first being a screened grid high frequency valve transformer coupled to a grid leak detector valve, and followed by two transformer coupled note magnifiers.

The aerial is coupled to the first tuned circuit either directly by means of a coupling coil or through one of three fixed condensers, depending on the size of aerial employed.

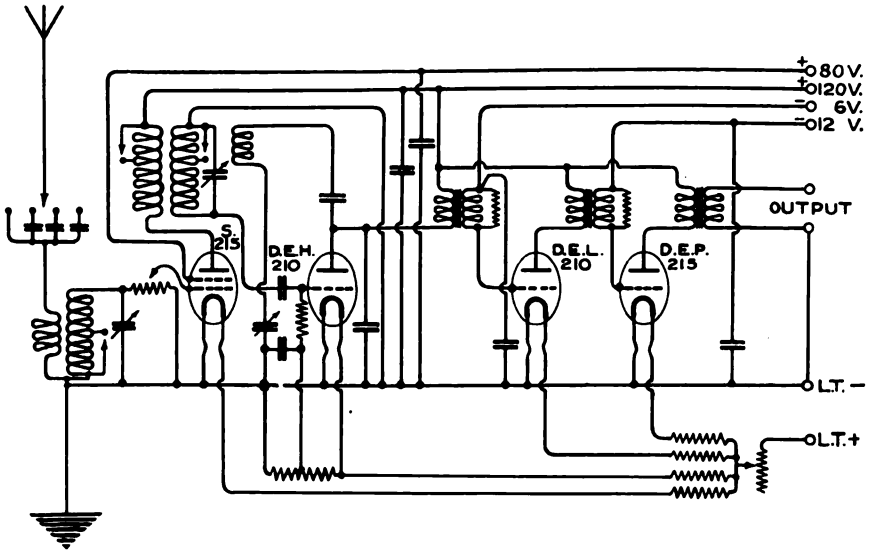


FIG. 2.

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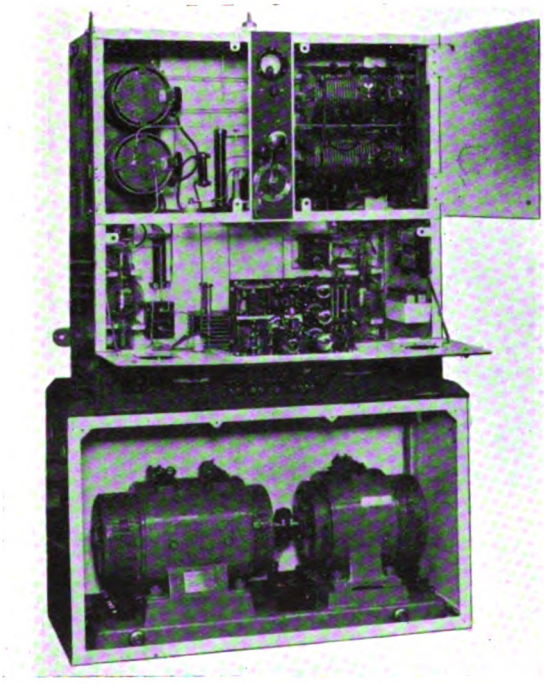
As the receiver will, in many cases, be used as a spot wave receiver, arrangements have been made so that when the receiver is adjusted to its correct wavelength, the waverange switch may be locked in position, and the single tuning control limited to give a small percentage search on either side of the spot wave.



The only adjustments then required are :—

(1) Volume control, by means of which overwhelmingly strong signals can be brought to reasonable strength smoothly and without distortion.

(2) Reaction control by means of a condenser supplied with a very smooth slow-motion device.

The high frequency circuits of the receiver are designed to obtain the selectivity arising from the use of two tuned circuits, while still embodying only one tuning control. The condensers tuning the H.F. valve grid circuit and the rectifier valve grid circuit are mounted on a common spindle. As the receiver may be used with various sizes of aerial, a fine tuning device is also supplied on the aerial circuit, to ensure correct " ganging " on any one particular wavelength. This is, in practice, used for fine tuning once the desired station has been found roughly. In the case of spot wave working, the two H.F. circuits are correctly " ganged " by this device on installation, and the fine tuning locked so that the number of tuning controls is still limited to one, excluding the reaction and volume control.

Receiver Aerial System.

The receiver will function satisfactorily with any aerial whose natural wavelength does not exceed the lower limit of the receiver waverange, *i.e.*, 150 metres. Under such circumstances no series condenser is necessary. In the case of an aerial being used whose natural wavelength does exceed this limit a suitable aerial series condenser must be connected in circuit.

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THE DESIGN OF WAVE FILTERS

The following article has been written by an engineer of the British Broadcasting Corporation, and is published in these pages by the courtesy of that organisation.

Whilst professing no claim to originality, it is believed that this collection of material will be found to present, in a succinct form, much valuable data of use to the practical engineer interested in filter work from the Radio view-point.

General.

THE subject of this paper has been dealt with at great length by many telephone engineers, notably G. A. Campbell and O. J. Zobel of the Bell Telephone System. While the exposition of the theory has been dealt with by many others, yet it is possible that for the purposes of engineering design the subject can be somewhat simplified, in order that the methods adopted in practice when designing a filter structure to fulfil certain requirements may be more clearly seen.

The object of this article, then, is to show the method of designing filter circuits from the engineering rather than from the mathematical point of view. It is not possible here to enter fully into every problem encountered in filter design, as many cases arising in practice require much manipulation of the circuit theory from which the fundamental formulæ for wave-filters are derived.

It should be noted that the structures discussed in this paper are for the most part "ideal structures," *i.e.*, the inductances and condensers associated with them are considered perfect, no resistance being present. The theory of dissipative filters shows that provided the dissipation is low, the behaviour of the ideal section is, in the main, representative of the former. Certain important cases of the dissipative structure are, however, discussed elsewhere in this paper.

The design of a filter is dependent upon two main considerations. The former is the behaviour of the filter at some definite frequency or frequencies (*i.e.*, frequencies of cut-off or of maximum attenuation), and from it can be computed immediately the attenuation and phase change characteristics as functions of frequency. The latter determines, together with the former, the size of the elements required to make up the structure. It is very important to note that it is unnecessary to know the size of the inductances and condensers forming a filter in order to predict the behaviour of the structure. It is therefore possible to predict the characteristics of any type of filter section from general considerations, the values of the inductances and condensers being fixed according to impedance requirements.

It should also be borne in mind that the expression "impedance of a filter" has no meaning unless some particular frequency is specified. When it is said

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that a certain filter has an impedance of, say, 600 ohms, what is meant is that the circuit to be associated with the filter should have an impedance of this value, or that the impedance of the filter at some fixed frequency is 600 ohms.

When, after study of the calculated characteristics of a filter, the sizes of the elements are computed from a consideration of the impedance of the associated

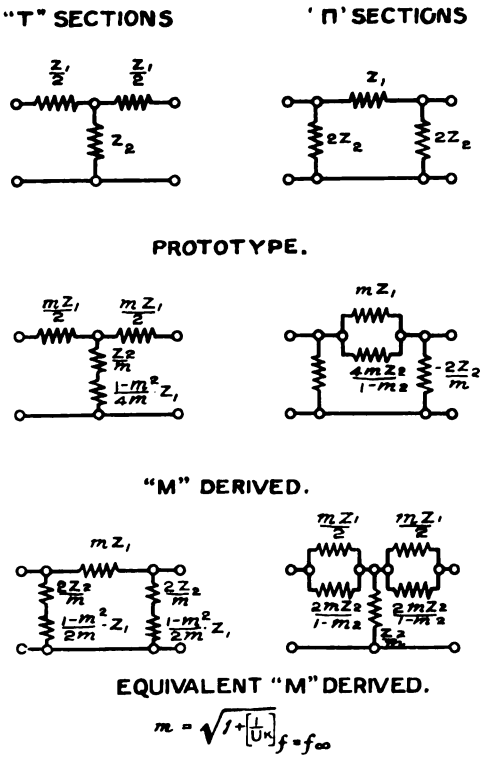

FIG. 1.

circuit, it is for the designer to decide whether the values of the inductances and condensers so found lie within the realms of practice or of absurdity. In the latter case, the impedance of the filter, or the type of section used, must be suitably modified.

2. Types of Filter Sections.

Filters may be classified into three main groups, from a consideration of their frequency characteristics –

(1) Low Pass.

(2) High Pass.

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(3) Band Pass [Band Elimination].

These three groups are further sub-divided into two types—

(A) The prototype, or simplest possible section representative of the group.

(B) The derived type (or "M derived" types, obtained from a modification of the prototype).

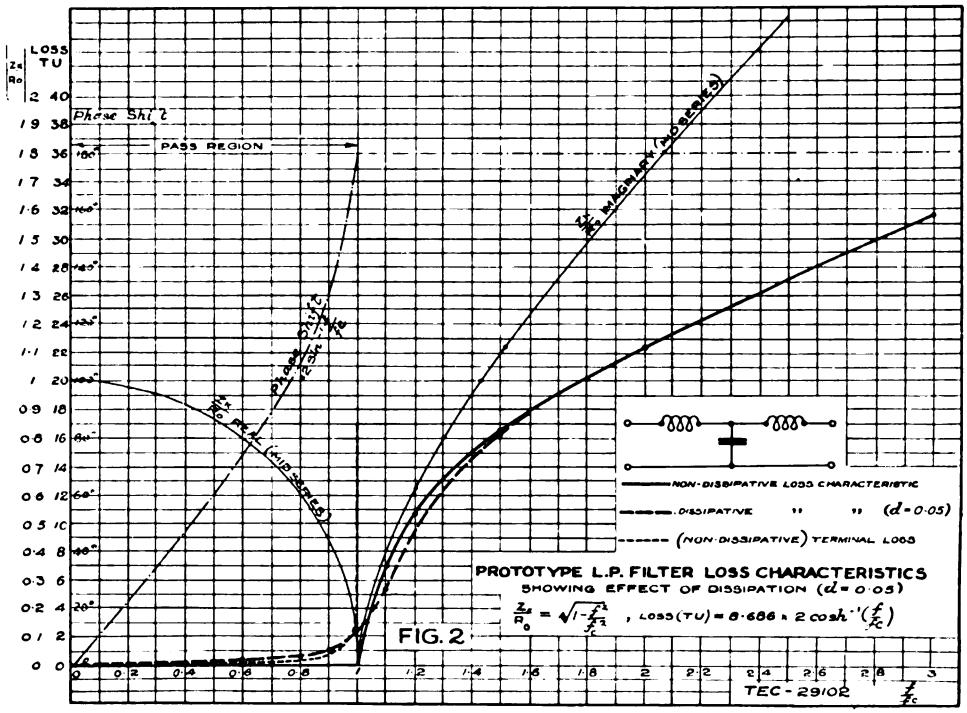

FIG. 2.

The prototype section is important, in that from it is obtained an infinite number of possible "derived" sections having very useful properties. The majority of filters used for telephone transmission purposes are composite, *i.e.*, made up of several dissimilar types having different attenuation characteristics but the same characteristic impedance. Prototypes alone are seldom used except in cases where discrimination between two remotely separated frequencies is desired, *e.g.*, filters for smoothing rectified A.C., etc.

In the theory of networks it is known that many types of section exist, which can be made equivalent as regards attenuation and phase-shift, although their

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impedances may be different functions of frequency. The main three types met with in practice are :—

(1) T, or mid-series sections.

(2) Π, or mid-shunt sections.

(3) Lattice, or bridge sections.

The first two types are closely analogous, and are shown represented on Fig. 1. The third type is shown on Fig. 7, illustrating a phase shifting network.

The derivation of the T and Π section is obtained from the general theory of networks as applied to an infinite number of sections having series impedances of Z_1, and shunt impedances of Z_2. The T section is then a symmetrical section taken at the mid-point of two adjacent series arms, while the section is the electrical equivalent of a symmetrical section taken at two adjacent shunt sections. The values of the series and shunt arms in the two sections are therefore $\frac{Z_1}{2}$ and Z_2 in the former, and Z_1 and $2Z_2$ in the latter case.

3. Formulæ for Wave Filter.

The expression connecting the impedances Z_1 and Z_2 with the attenuation and phase change can be shown to be

$$\sinh \frac{\Gamma}{2} = \sqrt{\frac{Z_1}{4Z_2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where $\Gamma = A + iB$

Γ is the propagation constant,

A is the attenuation constant, expressed in napiers

or $$\log_e \left| \frac{\text{Voltage into filter}}{\text{Voltage out of filter}} \right| = A = 8{\cdot}686 \times A \quad \text{Transmission Units.}$$

and B is the phase constant, expressed in radians, giving the amount of phase shift through the section.

This expression is true for both T and Π sections.

If in the above equation we equate A to zero, then we have the condition for no attenuation in the section. The solution of the equation then becomes

$$\sinh \frac{iB}{2} = i \sin \frac{B}{2} = \sqrt{\frac{Z_1}{4Z_2}} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

or $$-\sin^2 \frac{B}{2} = \frac{Z_1}{4Z_2}$$

The limits of $\sin^2 \frac{B}{2}$ are zero or 1.

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Hence for zero attenuation in the section,

$$\frac{Z_1}{4Z_2} \text{ must lie between 0 and } -1 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

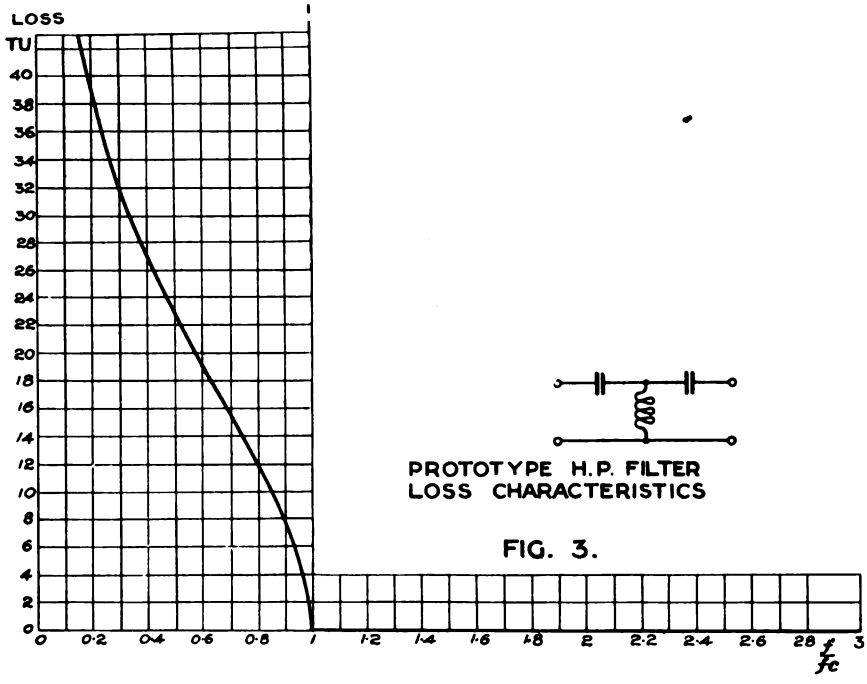
The ratio $\frac{Z_1}{4Z_2}$ is usually designated by U, and has great importance. The value of this ratio can be expressed in terms of any frequency f, and the frequency or frequencies of cut-off of all prototype sections. For example, let the prototype low pass section be considered. Then

$$Z_1 = i\omega L_0,$$

$$Z_2 = \frac{1}{i\omega C_0},$$

Hence

$$U_k = -\frac{\omega^2 L_0 C_0}{4} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$



PROTOTYPE H.P. FILTER
LOSS CHARACTERISTICS

FIG. 3.

(The suffix k indicates the value of U for a prototype section and the suffix m the value for an m derived structure.)

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But the frequency of cut-off f_c of a low pass filter is obtained from a solution of equation (3) —

$$\frac{\omega^2 L_0 C_0}{4} = 0 \quad \text{or} \quad -1, \quad \text{whence } f_c = 0 \quad \text{or} \quad \frac{1}{\pi\sqrt{L_0 C_0}} \quad \ldots \quad (5)$$

Substituting (5) in (4), we have

$$U_k = -\frac{f^2}{f_c^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

This illustrates the method of finding U for any filter section. The following table gives the value of U_k expressed in terms of f and f_c for the prototype low pass and high pass sections and for the prototype band pass section shown in Fig. 12, band pass section No. VII. The table also shows the attenuation as a function of the ratio of frequency to frequency or frequencies of cut-off.

PARAMETERS OF PROTOTYPE SECTIONS.

Section.	U_k	A
Low Pass	$-\frac{f^2}{f_c^2}$	$2\cosh^{-1}\sqrt{U_k}$
High Pass	$-\frac{f_c^2}{f^2}$	$2\cosh^{-1}\sqrt{U_k}$
Confluent Band Pass ..	$-\frac{\left[f_m - \frac{f}{f_m}\right]^2}{b}$	$2\cosh^{-1}\sqrt{U_k}$

where $b = \left[\frac{f_2}{f_m} - \frac{f_m}{f_2}\right]^2$ where $f_m^2 = f_1 f_2$, f_1 and f_2 being the upper and lower cut-off frequencies.

The practical significance of the foregoing equations is shown on Figs. 2 and 3, showing respectively the characteristics of low pass and high pass prototype sections. It should be noted that the characteristics hold good for all ideal prototype sections of the particular group, irrespective of their impedance or value of cut-off frequency, as for those two groups the attenuation has been shown to be a function of the ratio $\frac{f}{f_c}$. The meaning of the broken curves on Fig. 2 will be discussed later.

On Figs. 8 and 9 curves relating $U\left(-\frac{Z_1}{4Z_2}\right)$ with attenuation have been drawn. The significance of these curves is that for any ideal filter whatever, if U be calculated

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for any particular frequency, then from that value of U the value of the attenuation of the section can immediately be found. The use of these curves avoids to a great extent the recourse to a table of hyperbolic functions demanded by the equation for attenuation as a function of U.

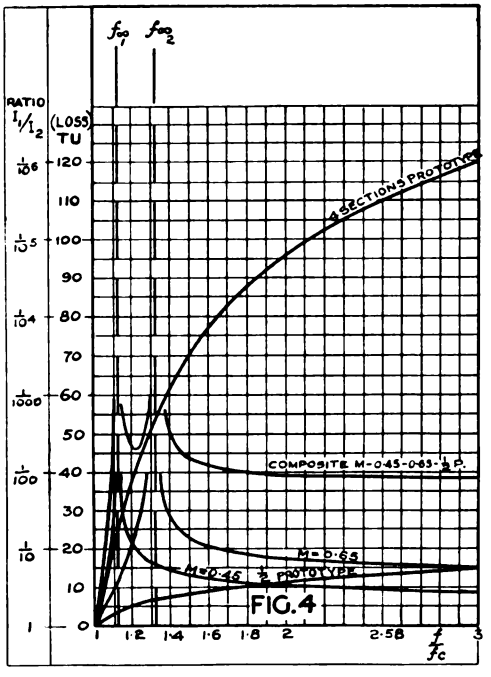

FIG. 4

In passing, it should be noted that f_c, the frequency of cut-off does not mean that at the frequency f_c attenuation is present. In an ideal filter f_c is the boundary at which the pass region ends and the attenuation begins; hence the attenuation starts from zero at the frequency of cut-off.

4. Effects of Dissipation on Prototype Sections.

In a prototype section the only sudden transition point lies at the cut-off frequency boundary or boundaries. The effect of resistance unavoidably present in the inductances of the section (that in the condensers can in most cases be neglected) is most marked in this region. On Fig. 2 the broken curve shows the effect of dissipative inductances on the attenuation constant of a prototype low pass filter. It will be seen that with the particular quality of coils used, the filter has begun to attenuate even in the pass region until at the frequency of cut-off the attenuation has risen to $2\frac{1}{2}$ TU. The effect of the resistance present is negligible for values of f/f_c higher than 1·5.

The same type of effect occurs in other types of filter sections, but does not seriously affect the behaviour of the filter, except at frequencies near cut-off or "infinite attenuation."

5. Impedance Variation in Prototype Sections.

The expression for the iterative impedance of a T network is

$$Z_k = \sqrt{Z_1 Z_2 (1 + U_k)} \quad \ldots \ldots \ldots \ldots \ldots \quad (7)$$

similarly for a Π section

$$Z'_k = \sqrt{Z_1 Z_2 / (1 + U_k)} \quad \ldots \ldots \ldots \ldots \ldots \quad (8)$$

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It should be noted that in the case of the prototype sections with which we are dealing, the product of Z_1 and Z_2 is a constant, independent of frequency. In the case of the low pass and high pass sections, for example, it is seen that

$$Z_1 Z_2 = \frac{L_0}{C_0}, \quad \text{or if} \quad Z_0 = \sqrt{Z_1 Z_2}\,; Z_0 = \sqrt{\frac{L_0}{C_0}} \quad .. \quad .. \quad .. \quad (9)$$

where L_0 and C_0 are the elements of the section.

Hence we can write

$$Z_k = Z_0\sqrt{1 + U_k}\,; \quad Z'_k = Z_0/\sqrt{1 + U_k} \quad .. \quad .. \quad .. \quad (10)$$

where Z_0 is of the dimensions of a resistance, say R_0.

Note that $Z_k Z'_k = Z_0^2$

If then we give U_k its value in terms of frequency ratios, we can trace the variation of the characteristic impedance with frequency. On Fig. 2, the ratio $\frac{Z_k}{Z_0}$ is plotted against $\frac{f}{f_c}$, the law in this case being

$$Z_k = Z_0\sqrt{1 - \frac{f^2}{f_c^2}}$$

In the low pass case obviously $Z_k = Z_0$ if $\frac{f}{f_c} = 0$, *i.e.*, at zero frequency. At the frequency of cut-off $Z_k = 0$, or $Z'_k = \infty$. From the frequency of cut-off as $\frac{f}{f_c}$ increases $\left(1 - \frac{f^2}{f_c^2}\right)$ becomes negative and the iterative impedance becomes imaginary.

It can be shown that all ideal filters have real values of iterative impedance in their pass regions and imaginary values in attenuation regions. Further, the limits of the value of the impedance may be zero or infinity.

It is therefore apparent that the attenuation curves shown on Figs. 2 and 3 do not depict the entire behaviour of the filter section. It is obvious that there will be a further loss through the filter, owing to its impedances ceasing to match that of its associated circuits.

The dotted curve on Fig. 2 shows the attenuation in the pass region due to the change of iterative impedance Z_k. Such attenuation is known as "terminal loss." A curve giving the terminal loss between two circuits as a function of the ratio of their impedances (for real values of impedance) is given on Fig. 10. In the case of an ideal filter the terminal loss at the frequency or frequencies of cut-off is theoretically infinite; on Fig. 2 the terminal loss curve will be seen to rise very steeply as the

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frequency of cut-off is approached. In practice, however, the smallest amount of dissipation in the filter diminishes very considerably the maximum value of the terminal loss, so that its presence is made known by a progressive increase of attenuation in the neighbourhood of the cut-off frequency rather than by any sudden rise in attenuation.

The value Z_0 is usually loosely described as the impedance of the filter. It has been shown that the true characteristic impedance Z_k is a function of frequency, having the value Z_0 as one of its limits. It will be shown later that it is possible with the use of "equivalent *m* derived" sections to make Z_k nearly equal to Z_0 over a large part of the pass region, hence avoiding terminal losses.

6. The Derived Type of Filter Section.

On Fig. 1 are shown the T and Π networks in which Z_1 and Z_2 represent the elements of a prototype filter section. In a prototype section, the frequency or frequencies at which the attenuation is a maximum (infinite in the case of ideal filters) are either at zero or infinity. The object of deriving a new type of structure is to make the attenuation a maximum at some finite frequency f_∞, the suffix ∞ denoting that the attenuation should be infinite at this frequency.

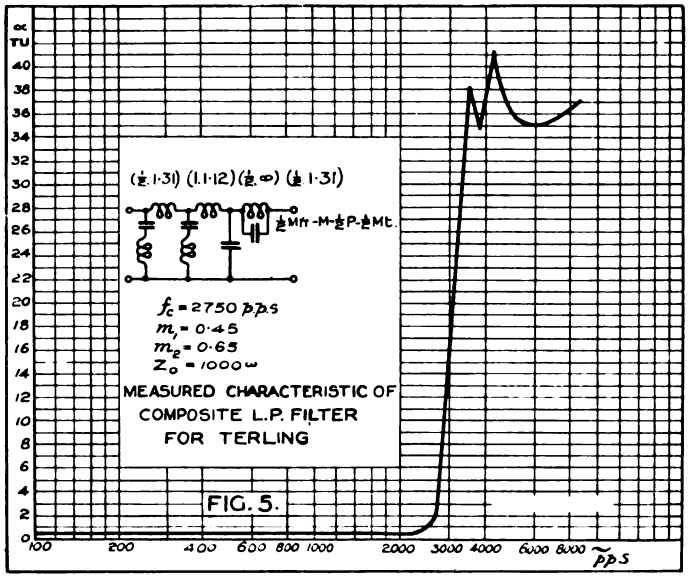

FIG. 5.

The derivation of such a type of section is rendered easy by the use of a parameter "*m*," which is determined from a knowledge of the frequency of cut-off and the frequency at which infinite attenuation is required. The properties of the

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"*m* derived sections" as regards their attenuation-frequency characteristic, are shown on Fig. 11, which represents a family of curves for five values of *m* for all ideal low pass and high pass "*m*" derived sections.

The value of *m* is given by the general equation

$$m = \sqrt{1 + \left(\frac{1}{\alpha_k}\right)^2} \qquad f = f_x$$

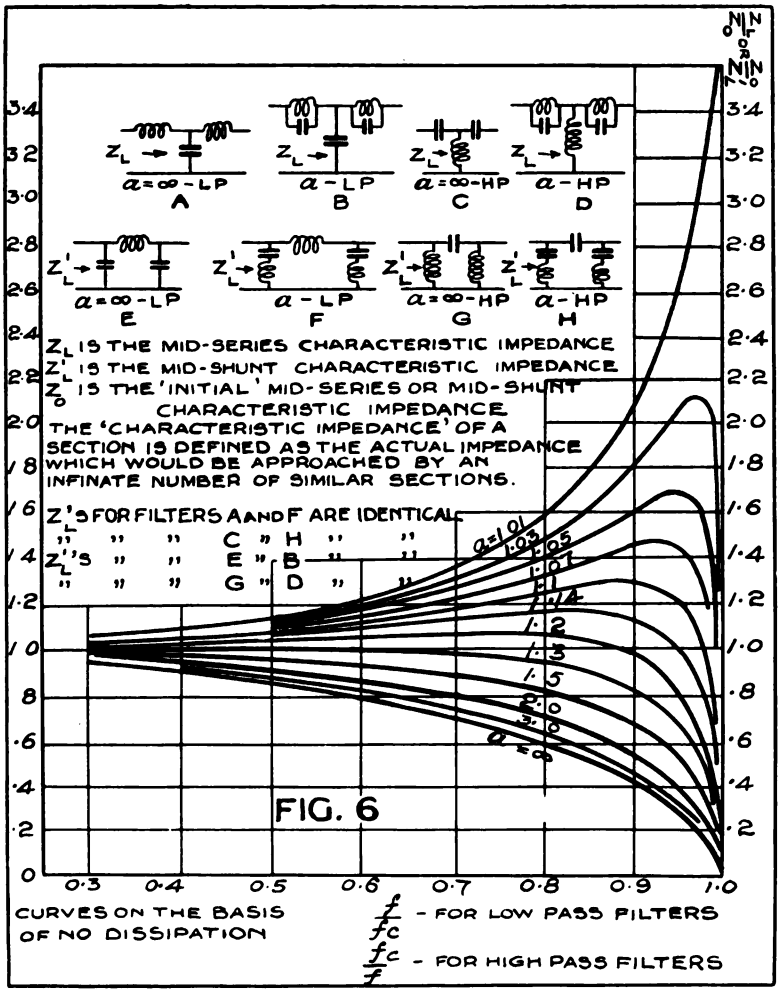

Fig. 6 is taken from "Telephone Transmission Circuits," by K. S. Johnson, *vide* Bibliography at end of article.

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where $\underset{f=f_\infty}{Z_k} = \frac{Z_1}{4Z_2}$ for the prototype section at $f = f_\infty$.

If we consider a prototype T section, and multiply the impedance of the series arm by m, and divide that of the shunt arm by m, it will be evident that in order that the expression for Z_k as a function of Z_1 and Z_2 in the new structure may be identical for that of the prototype, some third element will be required. It can be shown that this third element is in the shunt arm, and must be equal to $\frac{1 - m^2}{4m} \cdot Z_1$. Similarly in the case of the Π section an extra element is required in parallel with the series arm, of value $\frac{4m}{1 - m^2} Z_2$. If $m = 1$, the structure reverts to the original prototype. (See Fig. 1.)

It will be seen that the extra element required in the one arm is always some fraction of that in the other arm of the prototype. For example, in the low pass prototype T section, the added element is an inductance in the shunt arm, in series with the already existing condenser. The circuits so formed are thus either series resonant circuits in the shunt arm or parallel resonant circuits in the series arm (see Fig. 6, filters B and F).

It is self-evident that at the resonant frequencies of these circuits in the shunt or series arm their impedances will be zero or infinity respectively, so causing the attenuation at these frequencies to be infinite.

The value of m thus controls the value of the extra element to be added, and the computation of all the elements of the " m derived " section is merely a question of simple arithmetic, when the values of the prototype section have been obtained, and the value of m calculated from initial data.

Further, the characteristic impedances of " m derived " sections obey the same rule as the prototype from which they are derived, hence a composite structure can be made up without serious internal reflections taking place between adjacent sections.

On Fig. 12 the values of m in terms of frequency of cut-off and frequency of infinite attenuation are given for the various types of derived section.

From Fig. 11 it will be seen that the values of attenuation at the frequency $f = f_\infty$ all theoretically reach infinite values. Owing to dissipation this does not hold, and for a given quality of inductance used, the value of maximum attenuation decreases rapidly as m decreases.

Fig. 13 shows the locus values of the maximum attenuation in dissipative filters for various ratios of $\frac{\omega L}{R}$. This curve is used in conjunction with Fig. 11.

(To be Continued). W. Proctor Wilson.

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MARCONI NEWS AND NOTES

THE MARCHESE MARCONI

Senatore Marconi has received many honours from countries throughout the world. A list of these honours perhaps more than anything else epitomizes at once the service Senatore Marconi has rendered to science and mankind, and the universal recognition of the outstanding character of his work. In 1909 he was nominated by the King of Italy to a seat in the Italian Senate, and since the publication of the last number of THE MARCONI REVIEW the King of Italy has been pleased to confer upon Senatore Marconi another high honour in the hereditary title of Marchese as a further recognition of his life's work.

The Marconi Beam as a Link in World Wide Broadcasting.

A striking instance of the value of the Marconi Short Wave Beam system as a link in world-wide broadcasting was given on Sunday, July 7th, when the Thanksgiving Service in Westminster Abbey, London, for the recovery of the King was broadcast.

The King's recent serious illness had aroused the deepest feelings of concern in the hearts of British people throughout the world, which was shared by the people of all countries. There was, therefore, a widespread desire to hear the broadcast of the Thanksgiving Service, and an arrangement was made between the British Post Office, the British Broadcasting Corporation and the Marconi Company and its Associates for the broadcast of the Westminster Abbey service to be relayed to Canada by means of the telephone channel of the Marconi-Mathieu Multiplex Beam transmitter. So clearly were the signals received in Canada that not only was the service re-broadcast in that Dominion, but it was relayed through the Canadian Beam transmitter to Australia for re-broadcast in Australasia.

Although the Marconi-Mathieu Multiplex transmitter at Bodmin had been previously used for a series of very successful wireless telephony tests with Canada, it had not hitherto been employed for broadcasting. This was, therefore, the first time that it had been used as a link in a broadcasting chain. The result fully confirmed all expectations, the broadcast, both in Canada and Australia, being of the finest quality.

Details of the transmission are as follows: The service was transmitted from London to Bodmin by Post Office landline, and was there connected to the telephone side of the Marconi-Mathieu Multiplex Beam circuit for transmission to the Canadian Beam Receiving Station near Montreal. There the signals were transferred to the landline and passed along to the Canadian National Railway's and the Canadian Marconi Company's broadcasting stations by means of which they were broadcast

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throughout Canada. The Canadian Marconi Company's Beam station was also used to relay transmission across the Pacific to La Perousse, Sydney, Australia, and from Sydney it was re-broadcast throughout Australia and to neighbouring countries by the stations of Amalgamated Wireless (Australasia), Ltd.

The event was unique in the history of broadcasting. Letters from all parts of the Dominion have poured into the offices of the Canadian Marconi Company congratulating the Company upon the success of the re-broadcast, and expressing gratitude for the opportunity of listening to such a fine programme, and it is understood that Canadian listeners have commenced an active agitation for more inter-Empire broadcast programmes by Beam.

The comments on the quality of the transmission were that, in the opinion of the listening public, this broadcast was far better than any overseas broadcast hitherto attempted on the American continent, and was equal to a first class local broadcast.

That the excellence of this transmission was due to the Beam link is demonstated by the fact that listeners who attempted to pick up the transmission direct found that conditions were poor.

This experience shows that the use of the Beam system will be essential as a link in any satisfactory scheme of Imperial broadcasting.

Canadian Broadcasting Commission's Report.

The success of the broadcast of the Thanksgiving Service gives point to a paragraph which appears in the London *Observer* for July 14th, giving a forecast of the report of the Royal Commission appointed under the chairmanship of Sir John Aird, at the beginning of this year, to examine various methods of broadcasting control, and to submit to the Canadian Parliament recommendations to govern the future broadcasting policy of the Dominion. This Commission having taken a preliminary survey of radio broadcasting conditions in Canada, visited broadcasting centres in the United States of America, Great Britain, France and Germany.

According to the *Observer*, the Canadian Broadcasting Commission has now indicated, through its Chairman, the principles of its report. This will point out that although Canada has some excellent broadcasting stations, she is largely dependent on American programmes, and desires an increase in her own chain of broadcasting stations.

The *Observer* adds: "There is a general desire for British programmes to be transmitted by Beam wireless, and we are encouraged to look forward to the day when Empire programmes will be exchanged regularly between the Empire States."

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Telephony by Beam.

The broadcast of the Thanksgiving Service having been so successful, it occurred to the engineers operating the service that a test might be made of the apparatus for telephonic conversation between England and Australia via Canada. The test thus proved extremely successful, and for the first time a sustained telephonic conversation was engaged in between the two countries over this long route. July 7th will thus become important in wireless history as the date of the first duplex telephone conversation between England and Australia.

In this connection it is interesting to note that with rather experimental arrangements at Poldhu, the Marconi experimental station in Cornwall, intelligible speech was transmitted for the first time in history from England to Sydney on Friday, May 30th, 1924.

If apparatus similar to that used at Bodmin on July 7th had been available on the direct Australian Beam circuit, similar conversation could have been carried on direct with Australia without the intervention of any intermediate station, and this would be the normal method of carrying on wireless telephone communication with Australia.

A valuable point proved by Sunday's experiment was, however, the possibility of using the route through Canada as an alternative to the direct route to Australia, and the excellence of the voice reproduction and the ease of communication on this occasion demonstrated very clearly that the Beam without doubt will be the best method of carrying on long distance wireless conversations.

The Marconi Company to supply the Vatican Wireless Station.

The order for the wireless station which is to be erected in the Vatican City for the use of His Holiness the Pope and the Vatican State, has been placed with Marconi's Wireless Telegraph Company, Limited. The manufacture of the apparatus for this station and the plans for its installation have already been put in hand, and will be carried out with the greatest possible expedition.

The station will embody the latest improvements in wireless design and construction, and it is receiving the personal supervision of the Marchese Marconi. Communication will be carried out both by telegraphy and by telephony on the short wave broadcast principle, and the range of the station will be world-wide.

International Lighthouse Conference.

The first International Lighthouse Conference was convened by the Corporation of Trinity House and held in London from July 8th to July 12th.

At this Conference, at which all the principle foreign nations were represented, technical matters relating to lighthouse illuminating apparatus, fog signals and other subjects concerning lighthouse administration were discussed.

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The value and use of wireless formed one of the most important subjects considered, and the importance attached to wireless was shown by the fact that the special session at which the subject of wireless was discussed was more largely attended than any of the others.

Dungeness Lighthouse and Beacon Aerial System.

In opening the Conference, the President, the Duke of Connaught, said that within the last few years one of the greatest safeguards to the well-equipped vessel had been evolved in the form of direction finding by wireless, and the establishment round the coasts of wireless beacons by means of which the mariner could fix his position, particularly during fog, which is one of the worst trials to be encountered at sea.

Vice-Admiral Mansell, C.B.E., M.V.O., Deputy Master of Trinity House, who presided at the special wireless session, opened the discussion by saying that the introduction of wireless fog signals was perhaps the greatest advancement in modern aids to navigation. These radio beacons were now becoming general along coast lines where aerial fog signals had previously been established. Though other systems of directional wireless were being experimented with the beacon type of wireless fog signal had so far been universally adopted.

Mr. J. P. Bowen, Engineer-in-Chief to Trinity House, who entered fully into the subject, referred to the rotating Beam transmitter, the rotating loop beacon and the all-round beacon transmitter, and said it was the all-round beacon which had, up to the present, been universally adopted by those countries which had developed or were developing a programme of wireless fog signals, and it was this

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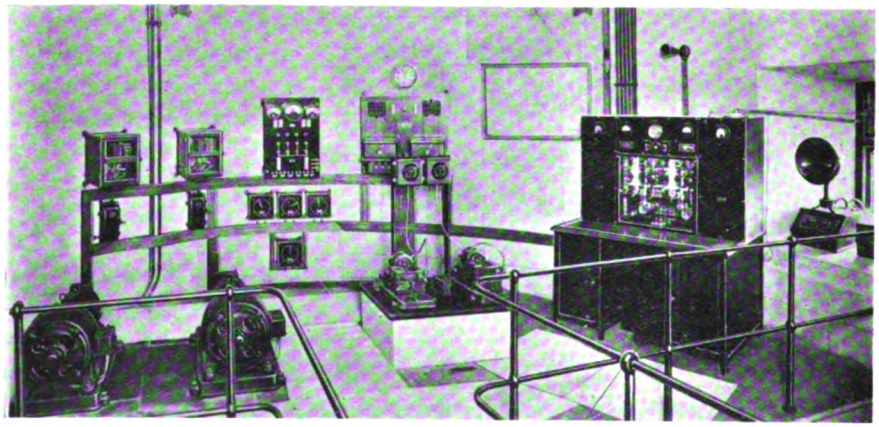
type which had so far been selected by Trinity House. Though requiring the provision of a somewhat expensive Direction Finding instrument on board ship, some of its advantages were :—

1. Comparatively low initial cost.
2. Low power and consequent low maintenance cost.
3. Automaticity and hence no additional personnel.
4. Availability for shore or lightship stations, and
5. Range of utility.

Moreover, a ship provided with a Direction Finder could take bearings on other ships in fog or ascertain the position of a ship in distress.

The whole equipment was automatic in operation from start to finish, and placed under the control of a master clock which governed the times and periods of transmission. All running machinery was in duplicate, and thus equipped practically no attention to the plant was required other than general maintenance, making the whole foolproof as far as possible.

Dr. Putnam of the United States said in his country there were 60 wireless beacons, and wireless seemed the only possible system now for sea signals.



Marconi Wireless Beacon Station, Type W.B.2, installed for Trinity House at Dungeness.

Visit to Dungeness Beacon Station.*

The Marconi Company has installed a number of wireless beacon stations around the coasts of Great Britain for the various lighthouse authorities, and the delegates to the International Lighthouse Conference visited the wireless beacon station which had just been completed at Dungeness, a photograph of which is published on this page.

* A technical description of the Marconi W.B.2 Beacon Transmitter appeared in MARCONI REVIEW No. 9.

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On another day the delegates paid a visit to the Marconi Works at Chelmsford, where they saw wireless apparatus of all kinds, including that for lighthouse services, being manufactured, and witnessed demonstrations of reception from beacon stations on direction finding receivers, the reception of Auto Alarm distress calls, telephony with wireless installations suitable for harbour and lighthouse services, and automatic calling apparatus used with these installations to avoid the necessity of a continuous wireless watch being maintained.

Wireless on Trawlers.

The use of wireless equipment on fishing vessels has now been an established practice over a sufficient period and in a sufficient number of cases to render possible an examination of its utility.

Reports received by the Marconi International Marine Communication Company from a number of steam trawlers on which Marconi apparatus is installed indicate clearly that its value is very considerable. Units of fishing fleets have been enabled to communicate throughout their operations and, by exchanging reports of fishing conditions, to concentrate on the grounds where working was found to be most profitable at the time.

In addition, by keeping in touch with the owners, the trawler skippers have been enabled to obtain last-minute market reports and to land their catches at the ports where prices were most favourable.

By providing these services, the wireless installations have generally proved to be extremely profitable investments for trawler owners, while the convenience of wireless communication in other ways is also appreciated among the fishing fleets. A very complete service of weather reports, independent fishing reports, and time signals is made available by wireless, and these auxiliary services have on occasion proved of incalculable value.

Practically all the Marconi-equipped trawlers carry $\frac{1}{4}$ kilowatt transmitters of the quenched-gap type, with 2-valve receivers—Type M.R.4C—having a wave range of 200 to 3,000 metres. With this apparatus trawlers are able to communicate with other trawlers and with land stations over distances of 200 to 300 miles and more.

A number of trawlers are also fitted with Marconi direction finders and direction indicators. These instruments provide at an economical cost an invaluable aid to navigation, independent of weather conditions, and in addition enable a vessel when called to any particular fishing ground by a sister-ship to proceed directly there by following the wireless bearing of the calling transmitter. In this way a trawler fleet, large or small, can be concentrated with the minimum of delay on the most profitable fishing grounds.

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The following extracts from reports recently received from Marconi-equipped trawlers demonstrate the practical utility of wireless apparatus to fishing fleets.

"After two days unprofitable fishing in the vicinity of St. Kilda the Captain requested me to enquire from some other trawlers the nature and amount of their catch. Having received the information required and found that results were no better than ours, the Captain gave orders to steam to the Minch, and after the first day's work the Captain found the results were very much better. I then called up another of our trawlers and gave the information that the results of the catch were very good. This eventually brought her to the grounds where we were, and after a few days in the above vicinity we sailed for Fleetwood, leaving the other trawler with what is hoped to be good fishing grounds where she would not have been but for our wireless."

"We received information from another of our trawlers where a fair living was to be had at fishing. This information was acted upon with result of a decent trip. Also information was passed on by me as I was control ship to all our other ships, three of them taking advantage of it."

"On leaving Fleetwood we received information of good fishing from the other vessels of the Company. We proceeded to position given and found fishing very good. We arrived in Fleetwood with a good catch of fish."

"Information was received by us of good fishing from two other vessels of our fleet. We proceeded to the position given at Black Rock grounds and made a good catch."

"We have been herring fishing this trip. We received markets from the owners which helped us to make moderate prices."

"The wireless has been of great value during the past trip—positions, soundings, etc., being received as to the whereabouts of good fishing."

"Good fishing news was received and we proceeded to the position given with the result that a very good catch was obtained."

"Communication was established with all coast stations passed within range. Communication was also established with all trawlers of this Company. All fishing reports exchanged satisfactorily."

"We reported good fishing at St. Kilda to all ships—two of our trawlers steamed 100 miles to our position, thus benefiting by the information."

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No. 11

THE MARCONI REVIEW

August, 1929

CONTENTS

A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS—III - - - - - - - PAGE 1

MARCONI AIRCRAFT TRANSMITTER - - - - 13

THE DESIGN OF WAVE FILTERS—II - - - 17

A MARCONI NAVAL TRANSMITTER - - - - 23

MARCONI NEWS AND NOTES—

MARCONI EXHIBITS AT THE INTERNATIONAL AERO EXHIBITION - - - - - 26

HISTORICAL MARCONI APPARATUS - - - 29

AERODROME GROUND STATIONS - - - 30

NAVIGATION BY WIRELESS - - - - 31

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THE MARCONI REVIEW

No. 11. *August, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS—III

PART II.—SOME USES OF THE SYNTHESIS MODEL, IN PARTICULAR THOSE RELATING TO WIRELESS PRACTICE

This article was commenced in the June number of THE MARCONI REVIEW. *In the following section the phase relationship of carrier to side bands is dealt with and the effects of alteration of their relative phases on the envelope. Examples are given to show what happens when the phases are shifted and what are the effects of frequency alteration. Further, the problem of suppression of one side band as well as the carrier is considered and some peculiarities of this system given.*

Section 2—The Phase Relationship. of Carrier and Side Bands and Suppressed Carrier System.

Carrier Suppression.

IN a previous section it was clearly shown that the present carrier system of wireless signalling is very uneconomic owing to the large proportion of power that is of necessity transmitted in the carrier, and it is of interest to discuss the possibility of carrier suppression.

Referring back to the brief definition of the high frequency spectrum, it is observed that all the intelligence is conveyed in the side bands. The carrier is of course essential; at the transmitter for the initial production of side bands, and again at the receiver for the purpose of improving its mentality. But since the carrier is merely a continuous wave of constant frequency and amplitude it need not be supplied with the side bands, but can, if desired, be suppressed at the transmitter, and a local carrier of the same frequency and phase added at the receiver, with a consequent saving of power efficiency.

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As it has been stated that a carrier must be produced at the transmitter, it may not be obvious how any power economy can be obtained, and although we are not concerned in this discussion with possible methods of working suppressed carrier systems, it may not be out of place to explain one or two features of circuits which have been used.

A carrier of small power is set up and modulated, thus producing side bands ; the carrier is then suppressed by some convenient circuit, an example of which will be described, and the side bands remaining are then amplified through a power amplifier of the usual design to the full power required for the final output. As a properly designed power amplifier has a large step up power ratio from stage to stage, one can assume that almost the full carrier power can be saved, as the initial carrier set up, which is suppressed at the first stage, would be of negligible power compared to the final output.

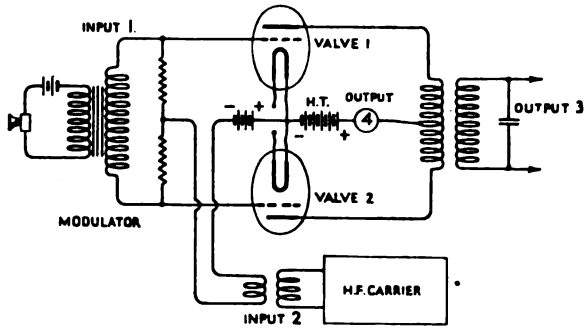

FIG. 8.

To suppress the carrier a filter is not used, as it is not entirely suitable for the suppression of a single frequency, but some form of balanced system is to be preferred, the best known being a type of "push pull" circuit as shown in Fig. 8.

We have in such a circuit two inputs, 1 and 2, and output at 3. Input to 1 acts differentially on the system as regards output 3, but input to 2 acts in opposition as regards this output. For any A.C. voltage applied from input 1 impulses the valves in anti-phase and because the feed to the two valves is drawn from the centre point of the output system, the anti-phase currents resulting become additive in action as regards this output system. On the other hand, any A.C. voltage applied through input 2 impulses the valves in phase and because of the centre point tapping, the "in phase" currents resulting oppose in action as regards output 3.

Of course, had the output been put in the common feed limb 4, the effects would be exactly reversed. If one considers the supply of input voltages of different

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frequency, say n and m, to inputs 1 and 2, outputs will appear of frequencies as shown in the following table :—

Input		Output	
1	2	3	4
m	—	m	—
—	n	—	n
m	n	m $(n+m)$ $(n-m)$	n

From this table it can be seen that if a carrier of frequency n, say, is applied to input 2 and a modulating signal to input 1, then at output 3, the carrier is suppressed and only the sidebands $(n + m)$ and $(n - m)$ appear. The signal component also appears, but if output 3 is a high frequency circuit, m need not be considered.

The advantage of such a balanced system is that the carrier can be suppressed even though the modulation frequency approximates to zero, thus producing side bands which are only a few cycles either side of the carrier, so close that a filter circuit would not be effective.

Having isolated the side bands, they can be amplified as required, or if one side band is wanted the output from 3 will be passed through any necessary filter system so that the lower side band is separated from the upper.

From the foregoing it is clear that there is no difficulty in suppressing the carrier from a modulated high frequency spectrum and transmitting only the side bands, thereby obtaining power economy, and in Fig. 9 is shown the beat wave produced by the side bands alone for the case of a sine signal*.

FIG. 9. *Carrier suppressed. Both side bands.* 100% *mod. Sine signal.*

If one traces out the signal component, it will be observed that the datum line of the signal wave now coincides with the zero line of high frequency, thus conforming to the definition of a non-carrier system, given in Section 1, but because of the image created, frequency doubling (with distortion) occurs. An interesting point to observe is the phase reversal which

* It should be noticed that where the word 'signal' is used in this article it applies to the modulating signal and not to the radiated signal complete with carrier.

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occurs at every half cycle of modulating component, which is analogous to the phase current change occurring in the line case. This can be seen clearly in the figure.

The automatic phase reversal makes it clear how the addition of polarising carrier at the receiver builds up the correct envelope shape ; for the side bands each being displaced on the frequency band an equal amount above and below the carrier frequency, when added to each other, form a beat wave of the carrier frequency, and if a homodyne carrier is added so that it is in phase with the one half cycle of the modulated wave it just pushes the envelope up, and because of the phase reversal, the carrier automatically assumes an antiphase condition with the second half cycle, the result being a corresponding reversal of envelope shape, and a correct reproduction of the original signal wave.

FIG. 10. *Suppressed carrier. Both side bands.* 100% *mod. Signal with 3rd harmonic.*

Fig. 10 shows the side band spectrum for a signal with a third harmonic in phase. Here again the datum line of the signal wave will be found to coincide with the zero line of high frequency and the phase reversal at the half cycle of signal is still in evidence.

If reception of this carrierless spectrum is considered it will be clear that demodulation will not give the original signal because the detector is unable to understand the meaning of the phase reversal at the half cycle, and in consequence the signal received will be of double frequency and distorted. To obtain the original signal it will be necessary to polarize the receiver with a high frequency carrier of the correct frequency and having the correct phase. The question that occurs is, can one obtain a frequency constant enough to be able to phase it and produce the required result, and what difference does a phase shift make on the envelope.

These points have been investigated and the results for the case of a sine signal are shown in Figs. 11 and 12.

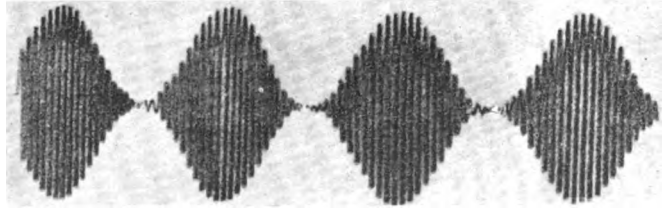

FIG. 11A. *Sine signal. Carrier correct frequency. Both side bands. Carrier correct phase.*

Figs. 11A, B, C and D are for the sine signal case and show the effect of the addition of a carrier of the correct frequency, but having a phase shift of different amounts, and from these figures it can be seen that distortion of envelope is considerable even with quite a small phase shift.

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Fig. 11A shows the carrier introduced at correct phase, Fig. 11B with a 10° phase shift, 11C with a 45° phase shift, and 11D with a 90° phase shift. It is to be noticed that a small phase shift introduces considerable distortion, and where the phase shift is 90° the distortion appears to take the form of frequency doubling. Unlike most frequency doubling the envelope produced appears to conform reasonably well to a pure sine wave of twice the frequency and half the amplitude. Note that a phase shift of carrier does not alter the phase of the signal wave on the time base but distorts.

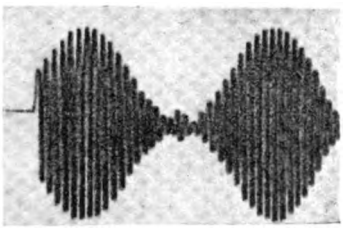

FIG. 11B. *Both side bands. Carrier* 10° *advance.*

If a carrier is introduced of a different frequency it will beat with the side bands spectrum and there will be transient conditions only where the envelope is produced correctly as shown in Fig. 12.

The conclusions one arrives at are, therefore, that, unless not only the frequency, but the phase of carrier, is correct, considerable distortion of signal envelope will result, and since it is practically an impossibility to obtain a correct phase, a suppressed carrier system is not a practicable proposition, except for I.C.W. telegraphy, where the character of envelope shape is of no importance. For telephony or facsimile work it is out of the question.

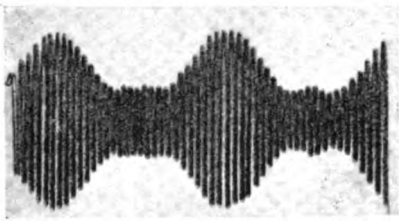

FIG. 11C. *Both side bands. Carrier* 45° *advance.*

Of course it is not really a matter of phasing—presumably this could be done if the frequencies of carrier and side band spectrum were the same—but the impossibility of keeping a high frequency wave constant to within narrow enough limits.

FIG. 11D. *Both side bands. Carrier* 90° *advance.*

We are accustomed to think of our driven transmitters as giving constant frequency, and further thinking of a zero beat case as showing that two frequencies are exactly the same. But a frequency constancy of one part in 100,000 is sufficient to give such conditions, whereas before one can consider phasing high frequency

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waves, a constancy of one part in several million will be necessary, even on a comparatively long wavelength.

Single Side Band Working.

To overcome the extreme difficulty of working a suppressed carrier, a compromise has been effected by adopting what is known as single side band working, and compromise though it is, this system is of considerable interest, for it reduces the frequency spectrum used to half, and further, helps to solve certain propagation difficulties encountered in ultra-short wave work.

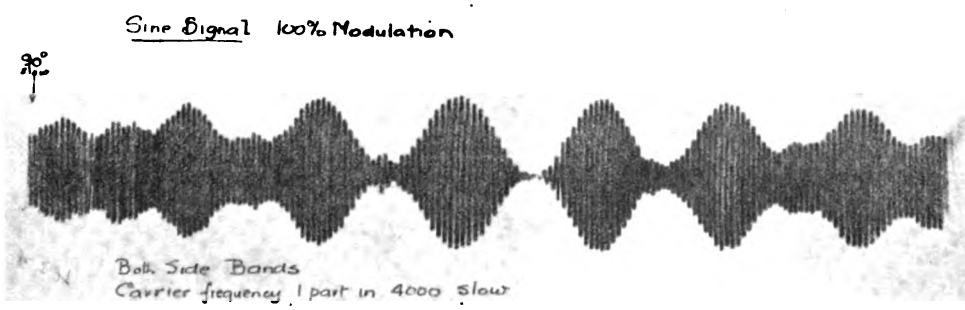

FIG. 12.

It should be pointed out, however, that single side band working has no power economy over full side band working with suppressed carrier. Further, it has its limitations and, as will be seen, it is not a perfect system.

Consideration of the original high frequency spectrum shows that either side band contains all the components necessary for the transmission of intelligence. Single side band working, therefore, consists of suppressing at the transmitter not only the carrier, but one side band as well. Thus one group of waves is transmitted in which are waves having the frequency of the carrier plus (or minus) the signal component frequencies.

Suppression of the carrier can be carried out by a balanced circuit, as described, the side bands being separated by some form of filter circuit.

As in the case of suppressed carrier working, to reproduce the signal at the receiver it is necessary to add a polarizing wave of the same frequency as that suppressed, as demodulation of the side band alone does not result in the extraction of the signal component.

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The usual theory of the action is that because the carrier differs from the waves of the side band by amount of the signal components, the beating of the group produces a synthesis wave whose envelope shape is the signal.

Thus in the case of a sine signal of frequency f modulating a carrier of frequency n, two side band waves are produced $(n+f)$ and $(n-f)$. Thus, if the upper side band is being received it will consist of a frequency $(n+f)$. The addition of a carrier of frequency n at the receiver before demodulation, produces a wave whose beat envelope will have a frequency of $(n+f)-n$, namely f, the original signal frequency.

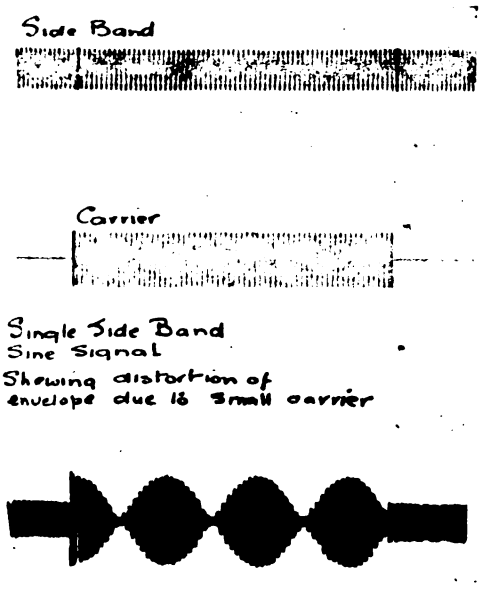

FIG. 13.

This simple arithmetic, however, is somewhat misleading, and it will be found that although f does appear as the chief frequency in the demodulated signal, the original envelope shape is not reproduced, although under certain conditions the distortion can be reduced to a small amount. Consider the case above for a sine signal. Single side band working for a sine signal is the transmission of a single wave differing in frequency from the carrier by amount of the signal frequency. Addition of a local carrier of the correct frequency certainly produces an envelope of the original signal frequency as shown in Fig. 13, but from observation the envelope is certainly not a sine wave. If the carrier added is large in amplitude compared to the side band the envelope appears to approach more to a sine shape as is shown in Fig. 14 which should be compared with Fig. 13 and this indicates that for single side band work a very large local carrier is necessary if good reproduction is required. Exactly how an envelope shape can change its character with change of the relative amplitudes of the beating waves is not easy to understand, but this result has been confirmed mathematically. Stated briefly, the mathematical expression for the rectified envelope of the beating of two simple waves in terms of these waves is not a simple function and such an envelope can only be expressed as the product of two simple functions. If the amplitude of one wave is infinitely large compared to the other one function goes to unity, thus leaving the envelope expressed as a simple function.

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The more pure the signal wave, the larger the carrier amplitude necessary to give correct reproduction. This is to be expected for the amplitudes of the harmonics of a signal are usually small compared to the fundamental and a carrier of given amplitude will be larger in proportion to the harmonics than to the fundamental, and hence the harmonics will be distorted least. Since it is the harmonics which give character, a signal having harmonics will be less distorted than one consisting of a single frequency, and this effect can to some extent be seen by studying Fig. 15, where the signal wave consists of a fundamental and third harmonic, and the carrier amplitude is of just sufficient amplitude to reproduce the envelope. Compare this with the envelope of Fig. 16.

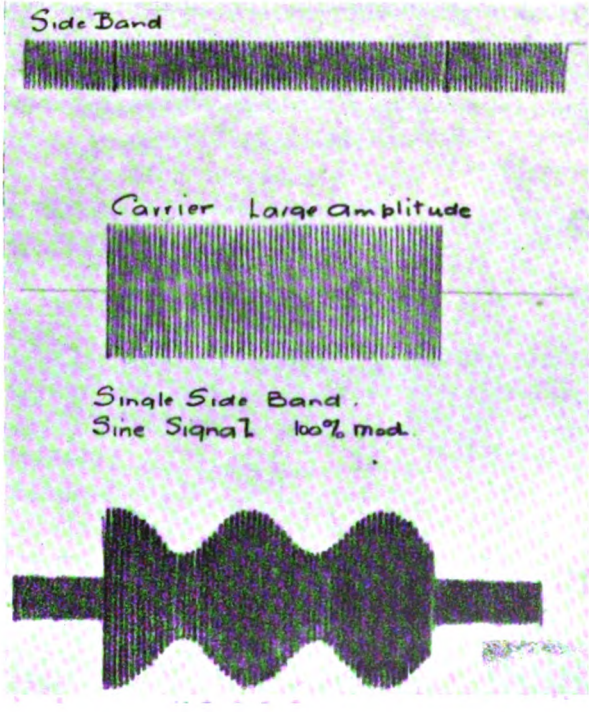

FIG. 14.

It is of interest now to consider various phase conditions of the added carrier.

Considering the sine signal case, since the side band consists of one wave only, it is obvious that the same envelope will be produced whatever phase is considered, although of course, the phase of envelope is not a constant. If we have a pure sine signal, then a phase shift of 90° of carrier will bring about a phase shift of 90° in signal, and thus if the carrier is replaced 180° out of phase the sense of the signal will be exactly reversed. This is different to the suppressed carrier case where a phase shift of carrier did not shift the signal phase but merely distorted. This phase sense does not matter for telephone work. If the signal is not a pure sine wave the different frequencies comprising it will all get different phase shifts as will be shown later.

It was felt that the sine case was not sufficiently comprehensive for an analysis of single side band working and therefore this system has been studied using a signal having a third harmonic. The original modulated wave produced by the transmitter

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for a signal having a third harmonic is as shown in Fig. 16. If we suppress the carrier and one side band what is radiated will be one side band only, say the upper, and Fig. 17 shows what this radiated wave comprises, from which one can see that the envelope appears to have no obvious relation to the signal. In this connection it is to be observed that it is extremely difficult to obtain any satisfactory physical conception of single side band working. For instance, a continuous wave telegraph signal might be single side band working of an I.C.W. signal.

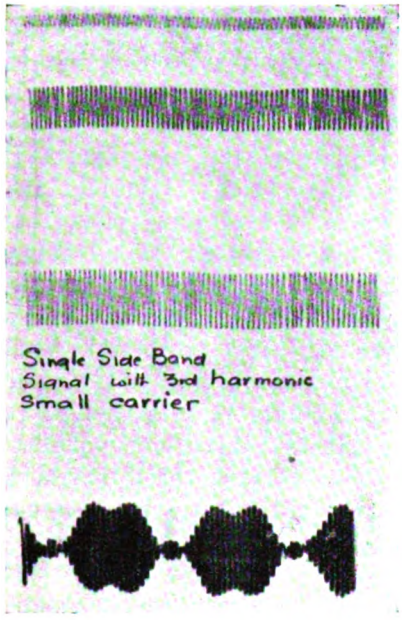

FIG. 15.

As stated previously, to be able to obtain the correct signal, it is necessary to add a carrier before demodulation, and it is of interest first to consider the introduction of a carrier of correct frequency but having different phases.

Fig. 18A shows a carrier introduced with correct phase, Fig. 18B with carrier 45° phase shift, and Fig. 18C with a 90° phase shift. Had the phase shift been 180° the envelope would have been completely reversed in sense. At first sight these envelopes look all different, but actually they all contain the same audio frequency components with different amounts of phase shift, and we must consider what effect this has.

In Fig. 19 is shown the resultant of a wave consisting of a fundamental and third harmonic, the latter having different phase shifts as indicated. If these waves are compared with the modulated envelope in Fig. 12 it is easy to observe that these modulated envelopes can always be identified with the third harmonic wave. Further the phase shift of signal harmonic is different to the phase shift of signal fundamental. Considering the case of the carrier introduced with a 90° phase shift, it appears that whereas the fundamental of the wave is shifted 90° the third harmonic is shifted 270°, *i.e.*, into anti-phase with the signal fundamental. This means that with a wave rich in harmonics not only will the phase of the fundamental be shifted but the phase of each individual harmonic shifted a different amount, and if one considers the general case it is observed that the phase shift of the different component frequencies is directly proportional to the frequencies. Thus, if one had a wave containing frequencies having multiples of 1, 2, 3, 4 and 5, if the carrier frequency is shifted 10°, then the phase shift of the frequencies of the envelope would be shifted 10° for the fundamental 20°, 30°, 40°, 50°, etc., for the harmonics.

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Because the shape of the resulting envelope depends upon the relative phases of the different components of the signal, then in single side band working, the envelope shape alters considerably with a phase shift of carrier. If, however, such a wave is being received aurally, the intelligence conveyed by ear to the brain will be exactly the same whatever envelope shape is made by the combination, for the ear is only capable of interpreting frequencies and amplitudes, and not phases. It interprets frequencies accurately, amplitudes indifferently, and phases not at all. This is true of all waves which are not transients in character. Thus, provided the same frequencies are present, (and no other), their relative phases do not matter, and their amplitudes only matter to a small extent. When one considers that the diaphragm of a recording telephone must vibrate to trace out the resultant wave, it seems amazing that the ear cannot detect any difference and the ear therefore appears to act as a very efficient phase destroying device.

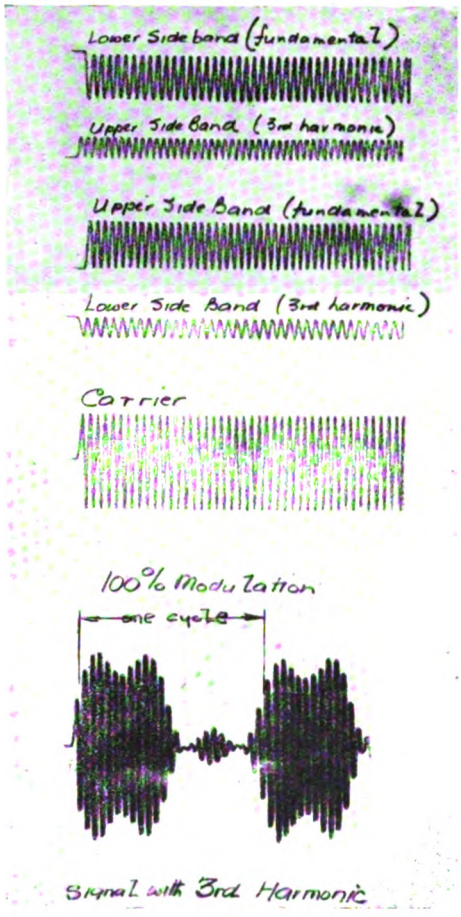

FIG. 16.

Thus one must be very cautious in interpreting the meaning of the shape of a modulated wave, or for that matter the mathematics of it, when it involves aural reception, or perhaps to put it another way, one must not take the results of aural reception as a basis of calculation for the behaviour of any type of detecting apparatus. For instance, single side band is quite sound for aural reception, but it would be out of the question for facsimile work where the detector is a glorified oscillograph and would record envelope shape. Apart from this point, as a matter of fact, it is difficult to see any possibility of single side band work, or suppressed carrier, for facsimile, on account of the fact that facsimile is a type of C.W. or square wave keying, varying

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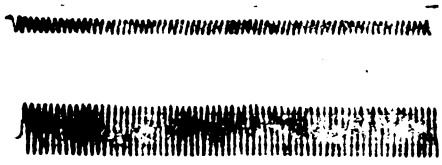

FIG. 17.

FIG. 18A. *Signal with 3rd harmonic. 100% mod. Single side band. Carrier of correct frequency. Normal amplitude.*

FIG. 18B. *Signal with 3rd harmonic. 100% mod. Single side band. Carrier misphased 45°.*

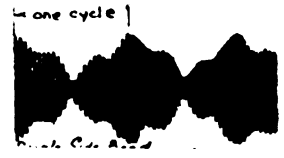

FIG. 18C. *Signal with 3rd harmonic. Single side band. Carrier misphased 90°.*

FIG. 20A. *Single side band. Signal with 3rd harmonic. Upper side band and carrier. Carrier frequency lowered.*

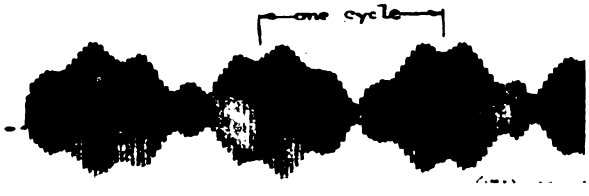

FIG. 20B. *Carrier frequency raised.*

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in speed from ultra high to zero. This means that the side bands at certain periods are separated from the carrier, but at other times they merge so toward one another and to the carrier as to make them impossible of separation by filters.

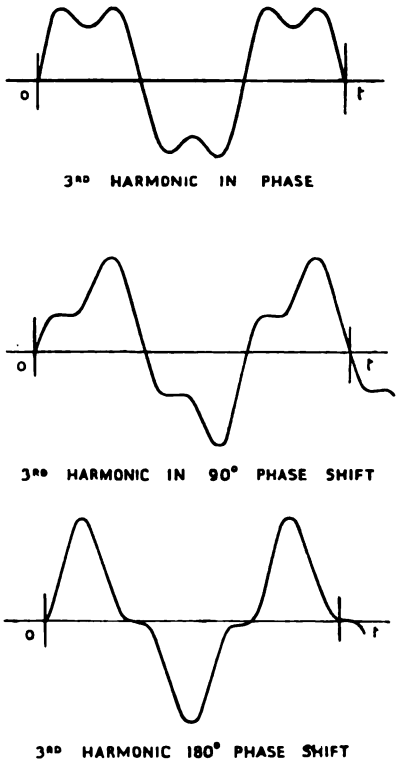

FIG. 19

There is one further point before concluding: the introduction of a carrier of a slightly different frequency.

If the carrier is altered in frequency the pitch of the fundamental will alter, and since the difference frequency to the harmonics change, the signal harmonics will alter relative to the signal fundamental, but it should be observed that because the signal fundamental has the smallest difference of frequency to the carrier, a small change of carrier frequency makes a larger change in the fundamental of the signal than it does to the harmonics. Now, if one considers an aural signal, the fundamental conveys mostly pitch and the harmonics mostly character and intelligence, and presumably because the harmonics are changed comparatively slowly compared to the pitch, one can stand for quite a remarkable amount of detuning before a speech signal becomes unintelligible, the most marked alteration being the rapid change of pitch. This effect is shown in Fig. 20, where a considerable alteration of fundamental pitch has been made, but the character of envelope can be seen still to contain much of its original characteristics. This fact may be the salvation of single side band work on ultra short waves, for, as far as can be seen at the moment, it is quite impossible to keep a carrier constant to a few cycles on these frequencies. The above statements are true for speech but not for the transmission of music. In the latter case much of the pleasure (or otherwise) of music lies in the combination tones of the various frequencies, and if these are upset, the result is discord.

The general inference is then, that single side band working offers a new field of development for certain classes of traffic, but that field will be limited to systems employing aural reception, unless distortion of envelope can be permitted.

A. W. LADNER.

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MARCONI AIRCRAFT TRANSMITTER

TYPE A.D.18

The Type A.D.18 transmitter represents a departure from standard aeroplane transmitter practice in that a drive oscillator is employed to stabilise the frequency of oscillation of the main transmitting system.

The set is designed chiefly for use in two-seater and larger aeroplanes, seaplanes and flying boats.

Any of the standard Marconi aircraft receivers can be used in conjunction with this transmitter, although a special receiver has been designed for use with the A.D.18 and will be described shortly in THE MARCONI REVIEW.

General Description.

THE transmitter is enclosed in a duralumin box whose sides are strengthened by corrugated duralumin strips, and whose front is readily detachable by means of ten spring clips. The box itself is supported on an elastic suspension system and is divided into four compartments, the first of which contains the valves, the second the independent drive circuit, the third the control panel, and the last the aerial tuning panel.

The disposition of these components can easily be seen from the photograph. The independent drive is completely screened from the remainder of the set and is provided with an automatic indicator which shows the wavelength to which the circuit is tuned.

To the left of the drive compartment are the four transmitting valves, details of which will be given later. In the middle compartment are the various controls, and the bottom compartment contains the reaction and aerial tuning circuits.

The set is adapted for use on either C.W., I.C.W. or Telephony, and has a wavelength range of from 300—1,550 metres when using an aerial system of approximately 0.003 mfds. capacity, this capacity being of the same order as that given by the ordinary type of trailing aeroplane aerial.

Owing to the limitation of space considerable experimental work has been necessary to ascertain the correct arrangement of the components for best results to be obtained; the most difficult of the problems arising in this connection being the disposition of the drive and magnifier systems, as it is not possible to separate these by more than a few inches.

Description of Circuits.

The circuit of the independent drive oscillator is given overleaf: Fig. 1.

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The valve used in this oscillator is an M.T.5B and the circuit is a modification of the well-known arrangement in which the coupling between grid and plate circuits is capacitative. This type of circuit is very stable. The output circuit of this oscillator is capacity coupled to the grid of the driven magnifier valve.

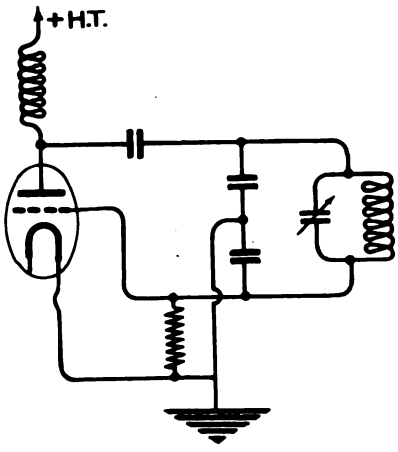
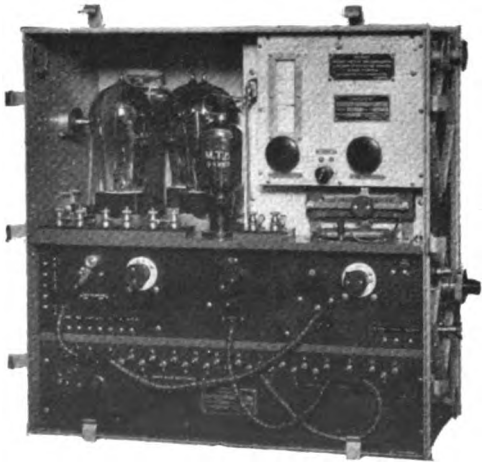


FIG. 1.

An indicating mechanism is provided on this circuit for tuning the drive to any particular wavelength. The handle which controls the drive closed circuit inductance switch also revolves a drum on which is marked a scale for each position of the stud switch. A pointer, which is geared to the variometer spindle, moves along these scales and indicates the exact wavelength to which the drive is set.

The magnifier system, consisting of two D.E.T.1 valves in parallel in the C.W. and I.C.W. position, and one D.E.T.1 in the telephony position, are capacity coupled to their output circuit, which consists of the aerial tuning inductance.

Self-oscillation of these valves is prevented by means of a semi-variable neutrodyne condenser which is adjusted to give zero coupling between the anode circuit (aerial tuning inductance) and the grid circuit (closed circuit of drive valve). The adjustment, once made for any particular wavelength, is found to remain sufficiently constant over the wave-range of the transmitter to render further adjustment unnecessary.



The Modulator valve system, which is, of course, only used on telephony, consists of two D.E.T.1 valves in parallel with the microphone current applied to their grid circuits by means of a step-up transformer. Modulation of the magnifier valve is accomplished by choke control in the usual way.

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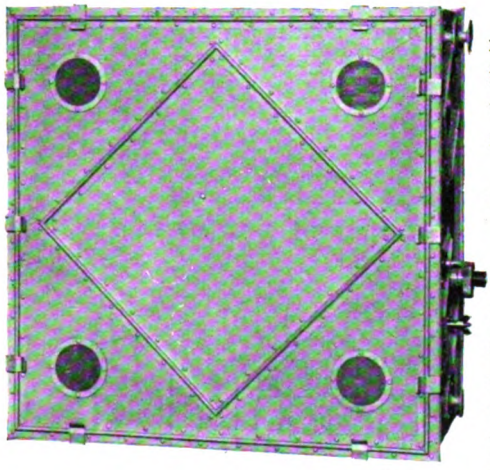
Keying.

Keying on the C.W. telegraphy position is carried out by breaking the grid leaks circuits and the negative H.T. supply simultaneously away from earth by the manipulating key, the action of which will be readily understood on reference to the diagram of connections in the C.W. and I.C.W. position.



On I.C.W. the grid circuit of the magnifier valve is broken at regular intervals by means of an interrupter which is mounted on the generator shaft.

Tuning.

The adjustment of the anode tap must be made by observing the total feed current of the valves. The set should be tuned to minimum feed and not to maximum aerial current, and the anode tap then adjusted to give the correct feed. If the set is tuned to maximum aerial current it is found that it will not be working efficiently and the valves will be overrun.

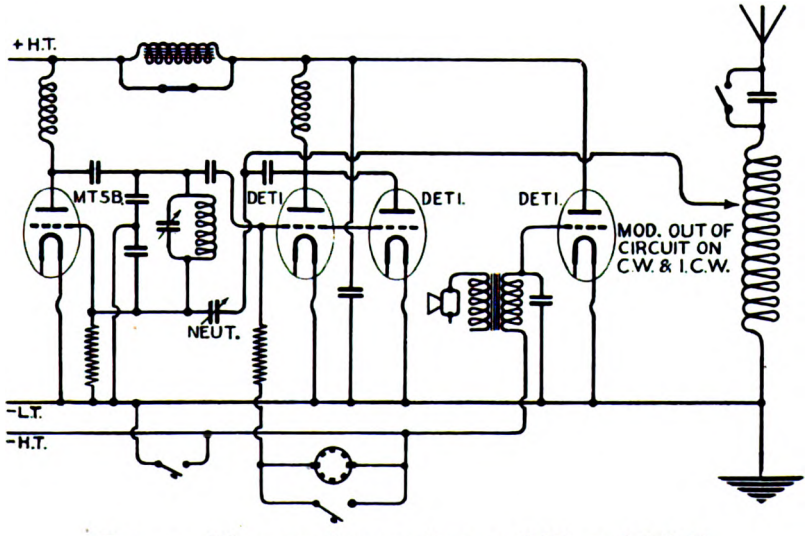


FIG. 2.—*Diagram of connections on C.W. and I.C.W.*

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Control.

Bowden controls are provided for the following purposes :—

(1) Switching over to I.C.W./C.W./Telephony.
(2) Switching from " Send " to " Receive."
(3) Tuning the aerial variometer.

An aerial ammeter and total grid milliammeter are provided external to the transmitter and mounted on a suitable instrument board.

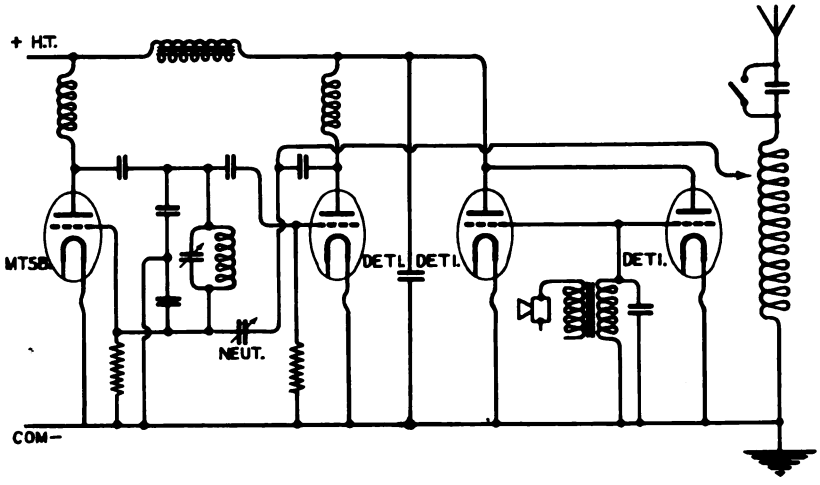

FIG. 3.—*Diagram of connections on Telephony.*

As a separate unit an instrument board with drive feed, modulator feed, and magnifier feed milliammeters on it can be supplied for testing purposes only.

Battery Supply, etc.

The main supply to the set is by wind-driven generator fitted with a constant speed propeller. This generator delivers H.T. current at 1,200 volts for the valves, and L.T. current to charge the 6 volt 25 ampere hour battery supplied with the set.

Range.

Assuming normal conditions and a Standard Marconi Aerodrome Station Direction Finder, such as a Type Rg.14 Receiver, the range from aircraft to ground with the A.D.18 are approximately :—

C.W. Telegraphy	400 miles.
I.C.W. Telegraphy	250—300 miles.
Telephony	150—200 miles.

The total weight of the complete transmitter equipment is approximately 124 lbs.

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THE DESIGN OF WAVE FILTERS—II

The first part of this article, published in the July number of THE MARCONI REVIEW, *dealt briefly with the following subjects :—*

(1) *General introduction.*
(2) *Types of filter sections.*
(3) *Formulæ for wave filter.*
(4) *Effects of dissipation on prototype sections.*
(5) *Impedance variation in prototype sections.*
(6) *The derived type of filter section.*

The concluding part of the article is given below.

---

7. Method of forming Composite Filters.

From the foregoing discussion of the " m derived " type of filter it can be seen that by suitable choice of various sections it is possible to obtain a sharper cut-off with fewer sections than would be required if prototype sections alone were employed. On Fig. 4 there are two main attenuation frequency characteristics, the one representing the characteristic of four prototype L.P. sections ; the other representing a composite L.P. filter having the same number of coils and condensers as the former. The remaining three curves are characteristics of the sections making up the composite filter. The sections are respectively one section of m derived ($m = 0{\cdot}65$), one section with ($m = 0{\cdot}45$), and one half prototype section. Addition of the attenuation constants for the various sections produces the attenuation constant for the composite filter. The values of m correspond to a ratio of $a = \frac{f_\infty}{f_c}$ of 1·32 and 1·12 respectively.

It is seen that the cut-off of the composite filter is considerably sharper than that of the prototype. The latter, however, for values of $\frac{f}{f_c}$ greater than 1·4 gives a higher attenuation than the former. If, however, the maximum attenuation required is only of the order of 40 TU, then the high attenuation of the latter is unnecessary, while the sharp cut-off of the composite filter is very useful.

Fig. 5 shows the measured attenuation characteristic of a composite filter developed along similar lines. The effect of dissipation is clearly seen by the rounding off of the boundary between the pass and attenuation regions.

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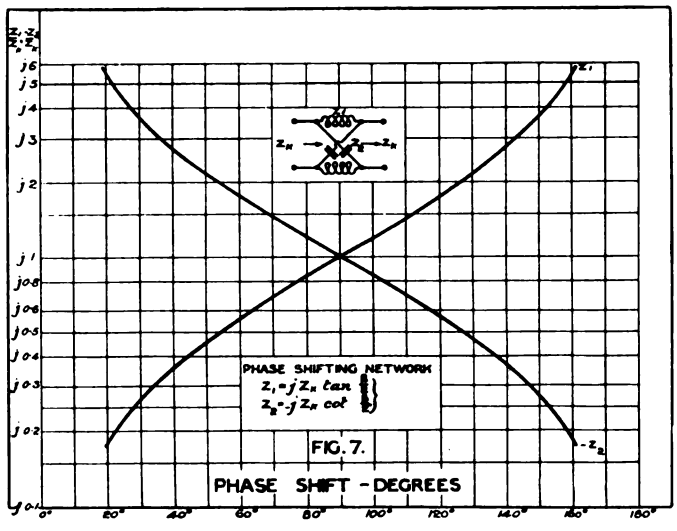

FIG. 7.

8. Constancy of Iterative Impedance in the Pass Region—Equivalent "*m* derived" Sections.

It has already been stated that the "*m* derived" and prototype filters have the common relation that their iterative impedances obey the same equations.

If now we examine the third set of sections on Fig. 1, called the "equivalent *m* derived" sections, we find that their relation to their neighbours immediately above them on the figure is simply that the "equivalent *m* derived sections" are the equivalent Π section derived from the T section above, and the equivalent T from the Π section above. In other words, the structural

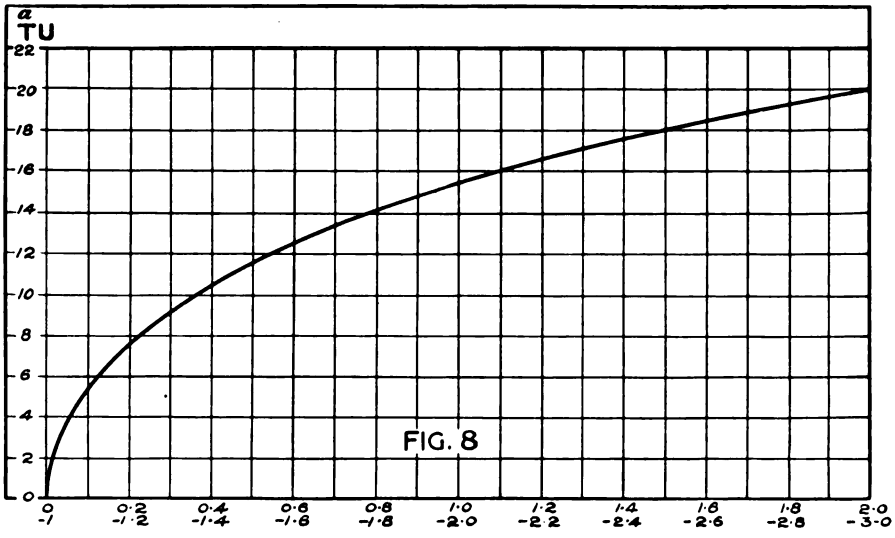

FIG. 8

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relation between the "*m* derived" and its equivalent is the relation between the prototype T and π sections.

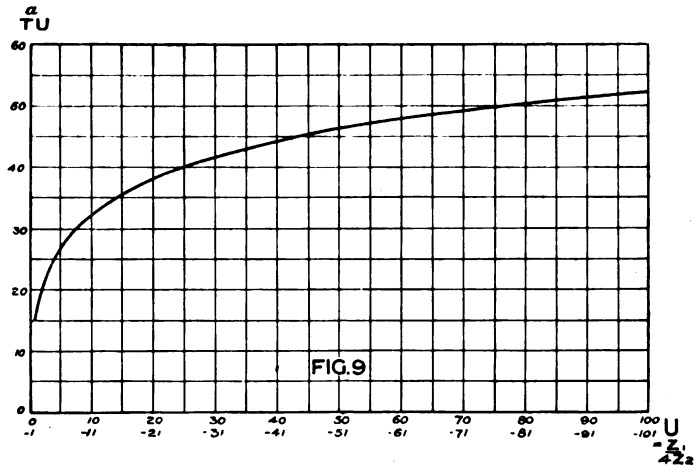

FIG. 9

We have now two new derived sections having precisely the same attenuation characteristics as the "*m* derived" sections already mentioned. The difference in this case lies in the fact that the equation for the characteristic impedance is no longer the same as for the prototype, but is now a function of *m*.

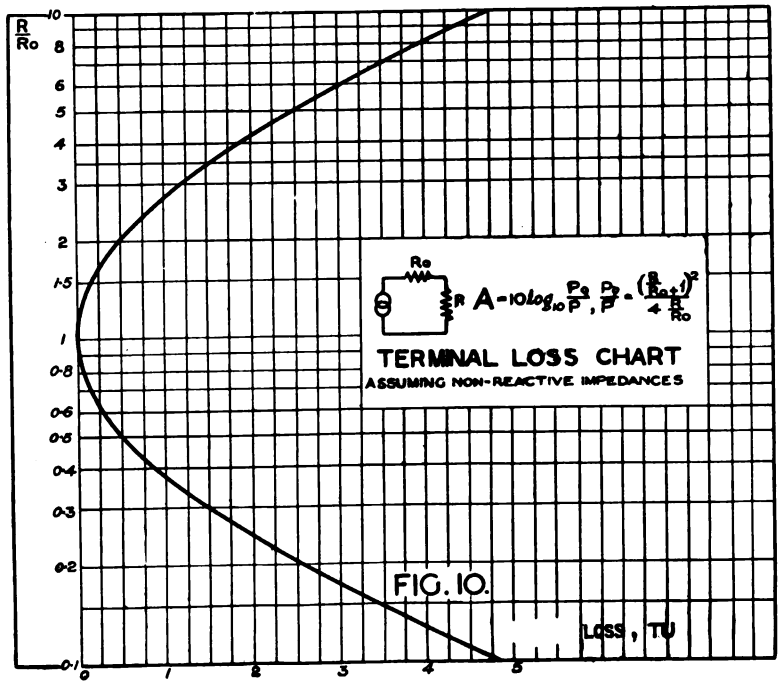

FIG. 10.

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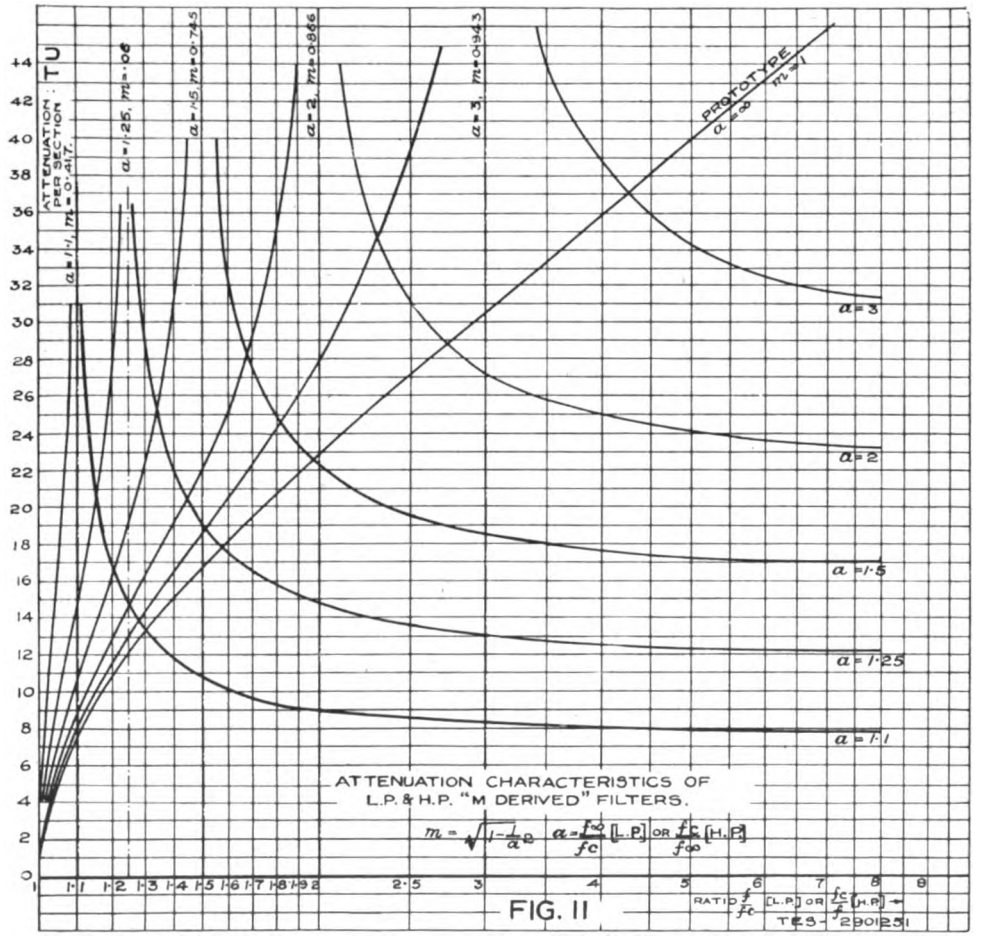
On Fig. 6 is found a series of curves showing the relation of the characteristic impedance in the pass region of all types of " equivalent m derived " low pass and high pass filters. It will be seen that for values of m near 0·6 (or for a value of $\frac{f_c}{f_c}$ or $\frac{f_c}{f_\infty}$ near 1·25) the characteristic impedance is approximately constant over


ATTENUATION IN TU
ATTENUATION PER SECTION
m = 0·417
a = 1·1, m = 0·417
a = 1·25, m = 0·6
a = 1·5, m = 0·745
a = 2, m = 0·866
a = 3, m = 0·943
PROTOTYPE
m = 1
a = ∞
a = 3
a = 2
a = 1·5
a = 1·25
a = 1·1
ATTENUATION CHARACTERISTICS OF
L.P. & H.P. "M DERIVED" FILTERS.
$m = \sqrt{1-\frac{1}{a^2}}$ $a = \frac{f_\infty}{f_c}$ [L.P.] OR $\frac{f_c}{f_\infty}$ [H.P.]
RATIO $\frac{f}{f_c}$ [L.P.] OR $\frac{f_c}{f}$ [H.P.]
TES-2301251
FIG. 11

the major part of the pass region. For this reason in a composite filter " m derived sections " having a value of m near 0·6 are generally halved, the two halves being placed at either end of the filter as " equivalent m derived " half sections. In this way the terminal losses at the input and output are minimised.

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9. Phase Shifting Structures.

The structures considered up to the present have the property of attenuating currents at certain frequencies, or bands of frequencies while (ideally) allowing others to pass through without loss. Consideration of the theory (Equation 1) shows that

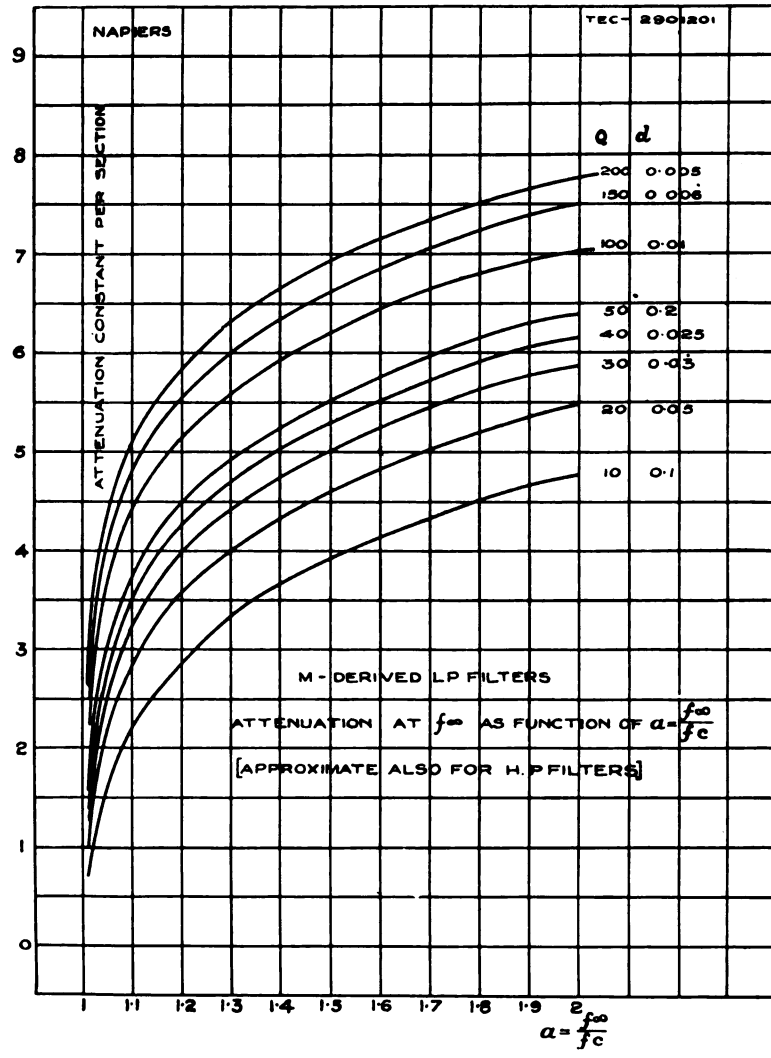

FIG. 12.

within the limits of a pass region the phase constant will vary between zero to $(2n + 1)\pi$, where n is integral. A consideration of Fig. 2 shows the phase shift

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in degrees through any ideal low pass filter section. It is seen that the phase change through the section progresses from zero to 180° at the frequency of cut-off, after which it remains constant.

Although use of a structure such as a low pass filter working within its pass region has been made in the past, yet there are disadvantages due to increase of attenuation as the frequency of cut-off is approached, and to the variation in impedance previously referred to, within the pass region.

The type of structure usually employed for phase changing structures is the lattice, or bridge type. Fig. 7 shows the circuit of a simple phase shifting section together with the derivation of its elements.

This section has no frequency of cut-off, and in the ideal case therefore never attenuates. Further, its characteristic impedance is a constant being independent of frequency.

Such structures are used with others derived from them to make up composite networks for phase-correction on submarine cable circuits for improvement in signal shape and picture transmission circuits over long trunk lines.

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W. Proctor Wilson.

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A MARCONI NAVAL TRANSMITTER

TYPE T.N.3

In THE MARCONI REVIEW *published in December of last year a short description of a Naval Transmitter Type T.N.1 was given. A further modification of this set has been designed using a coupled aerial system, but with the same input and output power ratings. This transmitter has been given the type title of T.N.3 and will be described in the following article.*

Similar switching devices to those used on the T.N.1 are incorporated in this new transmitter, and although, of course, extra controls are needed for the coupled aerial circuit, it is almost as easy to handle and adjust as is the T.N.1.

The salient features of the T.N.1 which have been enumerated in the article referred to above, such as robust construction, large waverange, etc., have been kept in the T.N.3 transmitter, and in addition, the coupled aerial circuit permits far greater selectivity to be obtained.

THE Type T.N.3 transmitter has been designed to cover a waverange of from 400 to 3,000 metres with a power of three kilowatts to the magnifier anode. The interchanging of the various combinations of inductances and condensers is accomplished from the front of the panel of the transmitter, and the various switches, etc., are provided with interlocking devices, to ensure the correct combinations and to prevent accidental damage when under power. Safety gates also automatically cut off the power when opened.

Power Supply.

The following machines are provided for the power supply to the transmitter :—

1. Motor alternator for H.T. supply.
2. Motor alternator for filament supply.
3. Motor generator for grid negative supply.

A small motor interrupter is also used for transmission on I.C.W.

The H.T. supply for the anodes of the valves is obtained by the transformation and rectification of the A.C. generated by the motor alternator. Double wave rectification is employed and two valves, type M.R.7a, are used as the rectifiers.

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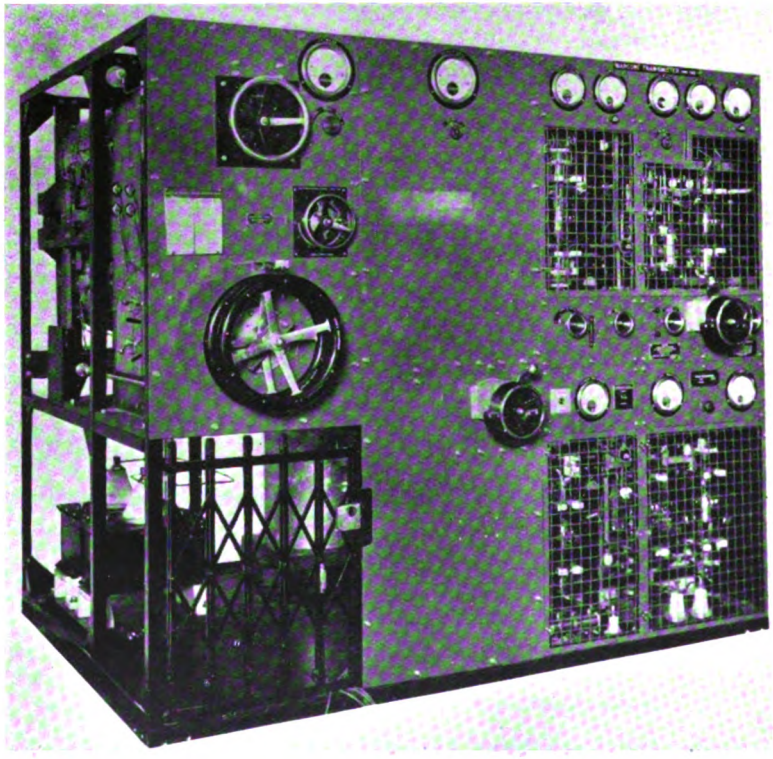
Circuits.

The circuits of the T.N.3 are similar to those described in the case of the T.N.1, and can be divided, as there, into four groups :—

1. The rectifier system.
2. The drive.
3. The magnifier.
4. The absorber.

These need no special description apart from what has been already given in con-



T.N.3 Transmitter.

nection with the T.N.1. The aerial circuit is, however, in the case of the T.N.3 entirely distinct from the closed circuit, and consists, as will be seen from the diagram of connections (Fig. 1), of a variable aerial tuning inductance, two fixed aerial series condensers, a tuning variometer, a variable coupling system to the closed circuit, and an aerial ammeter.

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Keying.

Keying is by the absorber valve method, and is accomplished by the reversal of the potential on the grid of the absorber valve. The scheme of grid negative

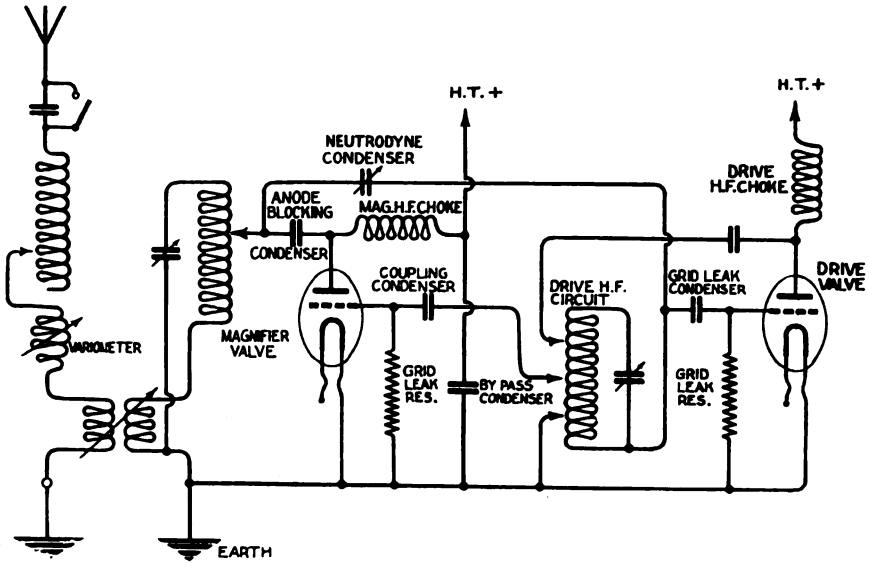

FIG. 1.

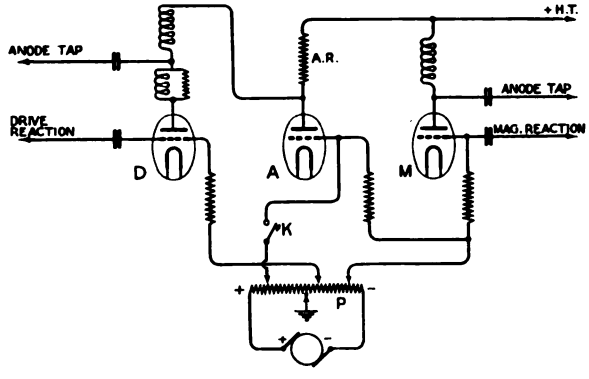

FIG. 2.

supply to the valves is shown in (Fig. 2), and it will be seen that, when the key K is closed the negative potential on the absorber valve A is changed to positive. The other valves D and M can have their grid potentials adjusted by the tappings on the potentiometer P. This keying relay K functions, of course, in the opposite sense to the manipulating key.

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MARCONI NEWS AND NOTES

MARCONI EXHIBITS AT THE INTERNATIONAL AERO EXHIBITION

The Marconi Stand at the Aero Exhibition at Olympia.

One of the most important technical exhibitions seen in Europe for many years was the International Aero Exhibition held in London from July 16th-27th. In the great halls at Olympia were displayed the leading aircraft of many nations, and aeronautical experts from all parts of the world gathered in London for the occasion.

The Marconi Company, whose wireless apparatus has played a considerable part in developing the safety and reliability of modern air services, was represented at Olympia by a stand that proved one of the most attractive and interesting in the exhibition. The theme of the exhibit was to demonstrate the importance of wireless to civil, military and naval aircraft services, and the apparatus displayed ranged from powerful transmitters for use in aerodromes to lightweight equipment specially designed for the light aeroplane which is now becoming so popular for the owner-pilot.

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The Marconi apparatus was displayed against a scenic background depicting a busy scene at a commercial airport, with the control tower and directional receiving aerials in the foreground and the masts of the aerodrome transmitting station in the distance. This panorama showed in a graphic form the utility of the apparatus displayed on the stand.

Exhibits of Popular Interest.

A new Marconi aircraft set that aroused great interest, particularly among private owner-pilots, was the type A.D.22 telephone transmitter and receiver, which has been designed along entirely fresh lines for use in light aeroplanes of the class that are highly popular among the flying clubs and for touring and sporting use. It is probable that this set will still further accelerate the popularity of the light aeroplane movement by simplifying the problems of aerial touring and enabling amateur pilots to obtain very much the same weather and aerodrome report services as are available to commercial machines. The importance of the contribution of such services to safety in the air is endorsed by international regulations, in force practically throughout the civilised world, requiring all passenger-carrying commercial aircraft to be equipped with suitable wireless apparatus.

The Marconi A.D.22 set will also provide owner-pilots with a means of position finding when they are flying over Europe or other parts of the world where there are aerodrome ground stations equipped with wireless direction finders, thus affording a valuable safeguard during periods of bad visibility.

For Commercial and Military Aircraft.

Particular interest was attached also to two " All-Purpose " aircraft sets of the popular " A.D.6 " series, which are fitted in commercial, military and naval aircraft in more than 30 countries. Those shown were the Types A.D.6h and A.D.6m. Both are combined transmitters and receivers, transmitting on a power of 150 watts, and are adaptable for telegraph or telephone working.

In the case of the A.D.6h, the waverange of the transmitter is 300-1,500 metres, and of the receiver 200-1,800 metres, while the waverange of the A.D.6m transmitter and receiver is 550-1,550 metres, thus completely covering the waverange allotted to aircraft by the Washington Conference.

The new Marconi short-wave aircraft transmitter, Type A.D.21, and short-wave aircraft receiver, Type A.D.20 (described in THE MARCONI REVIEW, No. 8 and No. 9 respectively), were examined with particular interest by many visitors, as was the Type A.D.19 transmitter, which is similar in design to the Type A.D.21, but is fitted with an independent drive for maintaining constant wavelength, and provides for telephone working in addition to continuous wave and interrupted continuous wave signalling.

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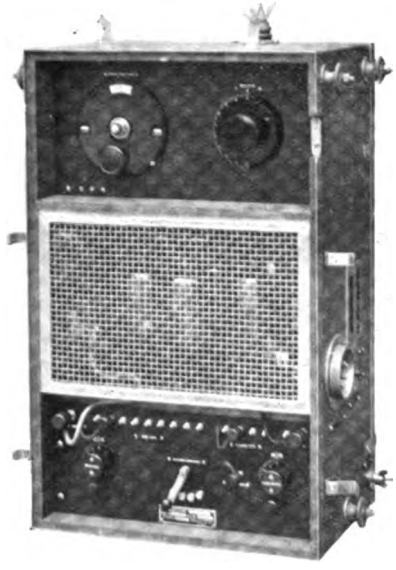
Also among short wave sets were the 75 watt Type A.D.5 transmitter and the A.D.12 receiver, which have proved their utility as a means of communication between small aircraft with fixed aerials. While specially designed for working together, the A.D.5 transmitter and the A.D.12 receiver are separately mounted for convenience of installation in small machines and because in the case of military aircraft it is often sufficient to fit only the squadron leaders' machines with both transmitter and receiver, and other machines with receivers only.



The Marconi Aircraft Telephone-Telegraph Set Type A.D.6m.

For Long Distance Air Routes.

With the inevitable development of aviation as a means of rapid long distance transport, with wide stretches of wild country or ocean to be traversed, the necessity arises for aircraft sets giving a long range of communication. On the Marconi Stand were exhibited two sets specially designed with this object in view. The Marconi Type A.D.8 telegraph-telephone set is particularly suitable for fitting in large types of aeroplanes, flying boats and airships, and the transmitter, being of 500 watts power, has a very wide range. This type of equipment is installed on the Short "Calcutta" flying boats used by Imperial Airways, Limited, on the Genoa-Alexandria section of the England-India air route.

The Marconi Type A.D.18 aircraft set also embodies a transmitter of comparatively high power (250 watts). This set was open to inspection for the first time at the Aero Exhibition, and—as in the case of all the aircraft apparatus—its light weight, compactness and accessibility were the subject of very favourable comment.

The Marconi aircraft direction finder, Type A.D.16, which is of particular value to aircraft operating over areas where direction finding ground stations are not available, was also shown. It operates on the Marconi-Bellini-Tosi system with fixed aerials, and is designed for a waverange of 600-1,600 metres, thus covering the standard ship communication wave and all wavelengths normally used in aircraft wireless practice.

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For aircraft on which a special operator cannot be carried a simple type of direction finder or "homing" device, the Marconi Type A.D.17, was displayed. This apparatus enables the pilot to steer directly towards a known wireless station, a loop aerial system, with a suitable amplifying and switch device, giving both aural and visual indication of the line of flight in relation to the wireless station.

Either type of aircraft direction finder is suitable for use in conjunction with the Marconi beacon transmitter, an example of which (Type W.B.2) was shown. Designed primarily for providing shipping in congested areas with reliable wireless signals for direction finding purposes, these instruments are equally suitable for providing similar services to aircraft.

Accessories.

The careful attention that is paid by the Marconi Company to every detail that facilitates the most efficient operation of their apparatus was demonstrated by the accessories on the stand.

They included the Marconi special "anti-noise" flying helmet, which is designed to assist good wireless reception in the air by excluding engine and wind noises; the Marconi aerial winch which automatically unwinds a trailing aerial at a steady and safe rate; and testing sets enabling aircraft apparatus to be tested on the ground.

Another accessory that proved of particular interest was the Marconi petrol engine, a two-stroke of 1 h.p. specially designed to provide a convenient power supply for driving the wireless generator of aircraft sets in the event of an emergency landing. The lightness, compactness and robust construction of this engine was noted by many of the eminent engineers who visited the Aero Exhibition.

Historical Marconi Apparatus.

An exhibit of unique interest was a display of historical Marconi apparatus. This included the transmitter, receiver and direction finder used by Admiral Mark Kerr in preparing for his Atlantic flight attempt in June, 1919, side by side with their prototypes used by Captain F. T. Courtney in July, 1928. A striking demonstration was thus afforded of the advances made in the design and construction of aircraft apparatus in recent years. Particular interest attached to Captain Courtney's apparatus, as he has acknowledged that his rescue when his flying boat was forced to descend in mid-Atlantic was entirely due to his Marconi apparatus. It enabled him to summon ships to his assistance although he had descended far out of the regular shipping routes, while by means of the Marconi direction finder he was able to assist the rescuing ships in their search.

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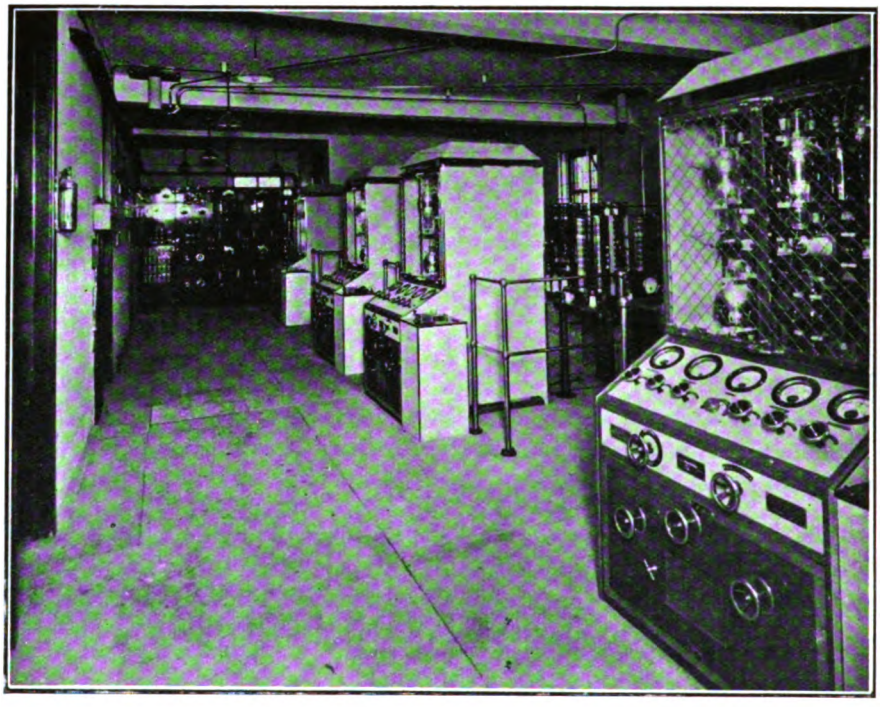

Four Marconi Type T.A.1 Aerodrome Transmitters at the Croydon Airport.

Aerodrome Ground Stations.

In all branches of aviation, the efficiency of the ground organisation may be said to be the keystone of success. This was emphasised by a number of features of the Aero Exhibition, and the importance of wireless in this regard was demonstrated by the Air Ministry's special display at Olympia as well as on the Marconi stand. The Air Ministry's display, which was one of the most striking features of the exhibition, included a Marconi 4 k.w. aerodrome transmitter, Type T.A.1, and a Marconi directional receiver, Type R.G.14, as installed at the London Air Port for communication with aircraft and with other aerodromes, and for position finding services.

On the Marconi stand was another transmitter suitable for aerodrome use, the Type U of 1½ kw. power, together with the Type D.F.M.4 direction finder receiver, which has been designed for use either on board ship or in land stations. The efficiency of this instrument may be judged from the fact that it has been adopted by the navies of several highly progressive nations.

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The attractiveness of the Marconi exhibit was shown by the large number of visitors from all parts of the world who spent a great amount of time on the stand examining the apparatus and discussing aircraft wireless problems, and it is gratifying to record that numerous enquiries and orders were received.

Wireless aids a Damaged Air Liner.

The use of wireless probably saved a serious accident to an air liner leaving Croydon for Paris during this season. As the aeroplane took off from the ground the aerodrome officials were horrified to see the undercarriage hit a piece of uneven ground and become partly detached. As the aeroplane rose one side of the carriage seemed to be hanging from the machine. The officials realising immediately that landing with a machine in that condition must be a hazardous affair and might even end in disaster, sent a wireless message to the pilot telling him of his predicament and ordering him to turn back and land without delay. As a result the pilot made a successful landing without accident.

Wireless in Warfare.

During aerial manœuvres in the United States recently there was a striking demonstration of the value of wireless on service machines. One aeroplane circled above Government Island in New York Harbour and was able, theoretically, to reduce the headquarters of the Second Army Corps to ashes. According to the *Daily Telegraph*, United States Army officers " applauded the fact that the aeroplane with its wireless and navigating equipment was able to remain in the air when other machines not similarly equipped were compelled to seek refuge at air ports. From the time the plane left its aerodrome 700 miles away until New York was reached it was in continuous wireless communication with successive stations and was able to keep on its course without any great difficulty.

" This is the first time in the United States that a plane has taken advantage of the network of wireless stations spread across the country. Despite rough weather over the Alleghany Mountains, also low clouds, drizzling rain, fog-filled valleys and extremely poor visibility, which obliterated all landmarks, the crew had throughout complete information as to their position and the weather ahead."

Navigation by Wireless.

The navigation of a ship from Finisterre to Liverpool through fog solely on wireless bearings is reported in a communication from the Master of the motor vessel " Athelking."

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The " Athelking " carries a Marconi Type 11F Direction Finder, and, commenting upon the efficiency of coastal wireless beacon installations used in conjunction with the ship's direction finder, the Captain states that he was able to take the usual four point bearings for some distance off in spite of the fog.

The report again emphasises the valuable aid rendered to navigation by wireless beacon stations, two more of which have recently been completed by the Marconi Company for Trinity House. Installed at Cromer and Dungeness Lighthouses, they will prove a very useful addition to the facilities available in the Channel and North Sea to ships equipped with wireless direction finders.

Dispersing Fog Dangers.

Following an announcement that the Institute of London Underwriters has agreed to suspend the additional premiums charged on the insurance of vessels calling at St. John, New Brunswick, when equipped with wireless direction finding apparatus, the following report received from a ship's Master on the value of the wireless direction finder for ships' navigation in Northern European waters is of interest.

Describing his experiences with a Marconi Direction Finder, the Master of a foreign steamer trading regularly to North Sea ports writes that the instrument " is worthy to be on every ship navigating in the Baltic Sea and in the North Sea, where there is so much fog and bad visibility."

He reports that bearings taken even from distances exceeding 100 miles have had a striking accuracy. By the use of the direction finder, he says, he knew exactly when to drop the lead to get his expected soundings in thick weather during a North Sea gale.

The stations upon which he obtained bearings were Scheveningen and Humber, and although the first of these was never nearer than 100 miles, the bearings obtained always coincided with those taken on the Humber station.

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No. 12

THE MARCONI REVIEW

September, 1929

CONTENTS

THE MARCONI ORGANISATION AT THE LONDON TERMINAL AIR PORT - - - - - PAGE 1

SHORT WAVE SIGNAL STRENGTH MEASURING APPARATUS—II - - - - - - 9

THE USE OF SHORT WAVES FOR LONG DISTANCE COMMUNICATION - - - - - 18

A SHORT WAVE PORTABLE MILITARY TRANSMITTER, TYPE Z.S.A. 3 - - - 22

MARCONI NEWS AND NOTES—

BRITISH REGIONAL BROADCASTING STATIONS 26

ICELAND BROADCASTING STATION - - 27

POLISH BROADCASTING SCHEME - - 28

STOCKBROKING AT SEA - - - - 29

SHIP-TO-SHORE TELEPHONY - - - 31

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THE MARCONI REVIEW

No. 12. *September, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

THE MARCONI ORGANISATION AT THE LONDON TERMINAL AIR PORT

The following article describes the routine methods which are in force at the Croydon Aerial Terminus to enable the aircraft wireless apparatus installed there, both in the case of ground stations and on aeroplanes, to be maintained in a high state of efficiency.

The instruments and procedure of testing the component parts of the installations are dealt with, and the reasons which led to the adoption of the present system are given.

EVER since the inception of civil aviation the Marconi Company has been actively engaged in the development and application of wireless as an aid to aerial navigation.

Ten years ago the first cross-channel aeroplane services were inaugurated by the Aircraft Transport & Travel Co., and the Handley Page Transport Co., from Hounslow and Cricklewood Aerodromes. At each of these places the Marconi Company established a service station for the purpose of fitting, testing and maintaining in efficient condition the wireless apparatus which, even in those days, was considered to be a useful adjunct.

At the Handley Page Aerodrome, Cricklewood, the Company also installed and operated a private ground station, which did much useful work until the time came when the Croydon Aerodrome was selected as the London Terminal for all cross-channel traffic. Our two service stations were then amalgamated into one depot, established at the new Aerodrome, where nowadays a very active organisation exists to serve the needs of Imperial Airways and a number of foreign lines which use the Air Port daily.

The great problem which confronts all those engaged in the exploitation of civil aviation is to obtain the maximum ratio of paying load to the total weight carried.

It will thus be seen how very reluctant the companies are to contemplate the carrying of a special wireless operator, even on the largest passenger-carrying machines.

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In the earliest days, therefore, it became essential to consider the possibility of making practical use of wireless telephony, as by this means the special operator could be dispensed with.

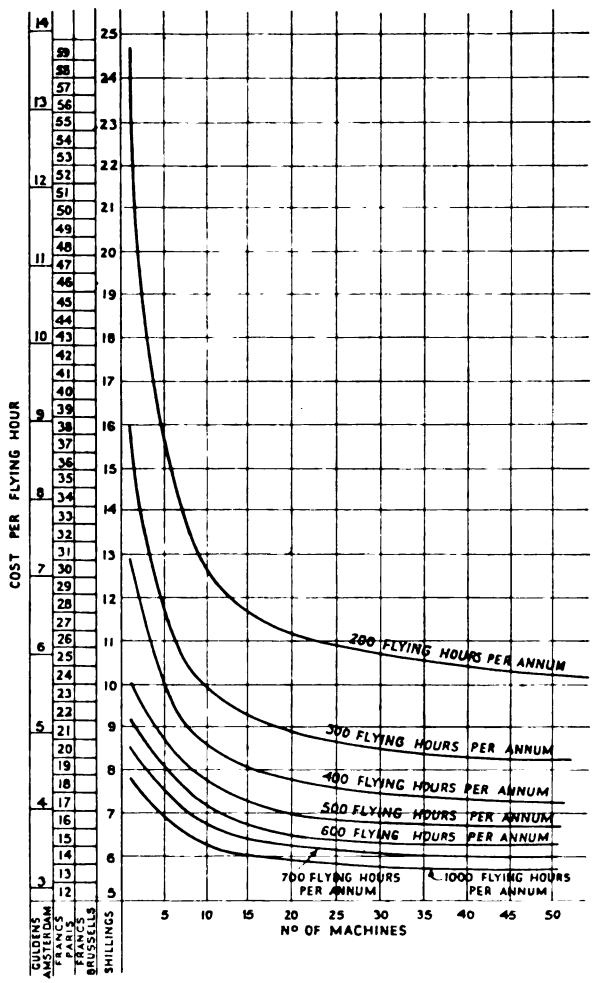

FIG. 1.

The Marconi Company were convinced, long before the advent of the broadcasting era, that in aerial communications there was a special application for wireless telephony; it was furthermore convinced that equipment could be designed which could be made sufficiently reliable to meet the very stringent requirements of commercial aviation.

After careful consideration of the problem the conclusion was reached that the most practical way of providing a service was to install, hire and maintain (by a system of ground tests) the apparatus for an inclusive sum per flying hour.

A sliding scale of charges was calculated and submitted to the authorities, and a rate agreed upon on the basis that only effective "flying hours" from a wireless point of view should stand for payment. This arrangement, which was suggested in the original instance by the Marconi Company, was equitable inasmuch as no payment was made for ineffective hours, and served to demonstrate in a practical manner that in those days, when some were sceptical as to the possibility of producing a wireless telephone apparatus which would give

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good results in flight, that the Company had ample confidence in its ability to solve adequately the difficult problems involved.

The diagram (Fig. 1) shows how the costs of the provision and upkeep of a given wireless installation, vary with the number of hours flown per annum, and the number of aircraft fitted.

This flying-hour scheme was accepted, and is still to-day in force (in a manner modified to suit present-day requirements) for British and some foreign machines as well.

The Marconi Company have also been the first to originate a Reciprocal Maintenance Scheme, in association with foreign companies, by virtue of which attention is given to the wireless equipment on British machines at foreign aerodromes, on request from the Pilot, while Dutch, Belgian and French aircraft are given any required attention when they land at Croydon.

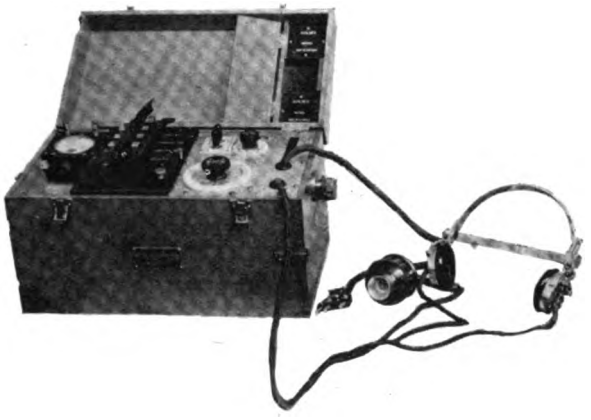

FIG. 2.

An office, workshop and stores are maintained, while special equipment has been developed for expeditiously testing the apparatus, either as installed on the machines, or in the workshops on the bench.

During the busy season there is often very little time available to the engineer in which to examine and check the performance of the apparatus prior to flight, and very little opportunity is afforded for witnessing results in flight.

Thus the engineer in charge has to rely on information obtained by ground test, by pilots' reports, and by special reports received by the ground station operators.

To facilitate routine testing, a special range of testing sets has been evolved, and a brief description of these may be of interest.

Firstly there is what is known as the No. 2 Testing Set (Fig. 2). This consists of a wavemeter unit and an artificial aerial unit, each fitted into a screened compartment, and both contained in a light wood box, readily capable of being carried into the cockpit of an aeroplane.

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A fixed amount of coupling is introduced between the two screened compartments.

In use the artificial aerial is connected across aerial and earth—thus replacing the trailing aerial in flight—and the wavemeter is employed to induce a signal of known strength (by virtue of the fixed coupling) into the receiver, which, if normal, will give a strength of signal comparable with that of a calibrated variable tone which, by certain switch connections, is obtained from the wavemeter buzzer direct. By this means the engineer can check, with sufficient accuracy for practical purposes, both wavelength and sensitivity of the receiver under test.

FIG. 3.

By the movement of a switch the transmitter can similarly be tested for wavelength, oscillation conditions and depth of modulation.

Arrangements are also provided for comparing the sensitivity of telephones and microphones, against a standard set provided with the testing set.

The No. 4 Testing Set (Fig. 3) consists of a set of instruments conveniently mounted and arranged to be automatically connected in the appropriate circuits, on being plugged into the set. By this means the anode voltage and current, and the low tension supply characteristics can be rapidly noted, and any necessary adjustment can be made.

The No. 2 Testing Set and No. 4 Testing Set, together with a set of tools, a hand-motor for coupling to the wind-driven generator, and a set of batteries for driving it, are all accommodated in a mobile testing equipment (Fig. 4), which can readily be wheeled alongside a machine on the aerodrome, if tests are required immediately prior to flight.

The description of this testing equipment is not complete without reference to the portable petrol engine (Fig. 5), which, coupled to a standard aircraft generator, provides a convenient source of power supply, when prolonged tests, under full power of the aircraft installation, are required on the ground.

Routine tests are classified under 4 headings, viz. :—

> "*A*" *tests* are undertaken as soon as possible after the aeroplane comes in after the day's flying is over. The installation in the machine is run up with the aid of the testing apparatus described above.

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"*B*" *tests* consist of bench-testing of transmitting and receiving apparatus.

"*C*" *tests*, which are similar to "A" tests, are carried out immediately prior to the departure of the machine. They are of necessity of a more cursory nature than "B" tests. By the aid of the 6-volt accumulator, which forms part of the standard aircraft equipment, the wind-driven generator is "motored" and made to supply just sufficient energy to cause the transmitter to oscillate, and the receiver to become responsive. An experienced engineer can judge from the results obtained whether normal results can be expected under flight conditions, in a few moments.

"*D*" *tests* are carried out when the aeroplane is in for "Dock overhaul," and comprises an exhaustive inspection and test of the complete installation, both on the bench and *in situ*.

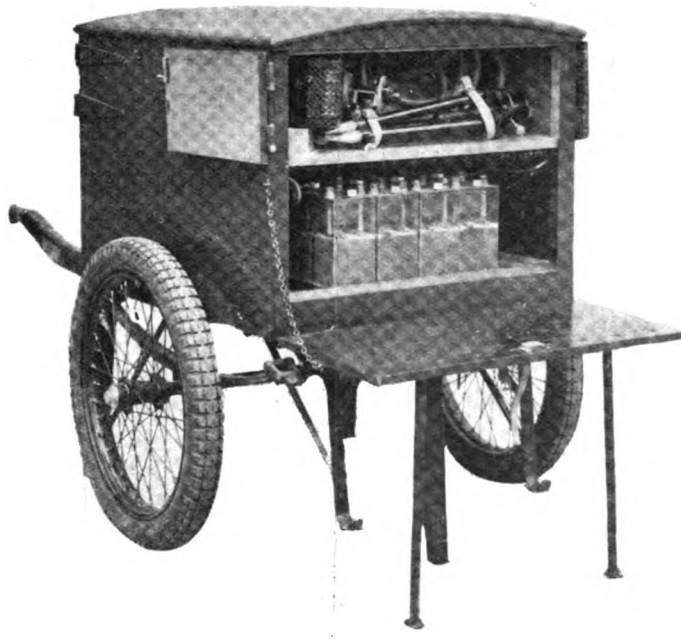

FIG. 4.

The conditions under which the apparatus has to work in an aeroplane are admittedly difficult. There is the engine and the propeller noise, which is to some extent mitigated by the use of a specially designed helmet (Fig. 6), in which rubber sponge is employed to surround the telephones, and thus to keep out a large measure of extraneous noise.

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Then there is the interference caused by the ignition system of the engine and its associated wiring.

All the metalwork is, or should be, bonded together so as to form a conductive whole.

When faults occur in bonding, or there is insufficient special or natural screening of the engines, grave interference is caused, which may seriously interfere with the proper working of the wireless equipment.

Electric lighting systems may also be a potent source of trouble, due to induction noises picked up by the radio receiver.

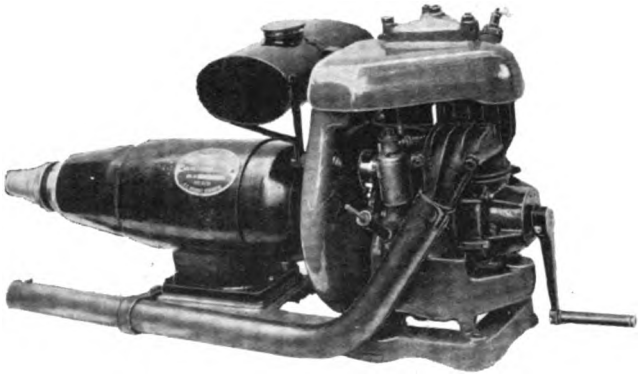

FIG. 5.

The maintenance of lights, the engine ignition system, bonding, etc., is a matter which is generally the responsibility of the aircraft owners, and hence, when trouble is experienced from these causes, action has to be taken by other authorities, in order to rectify the trouble.

Another source of inefficient working is interference due to jambing from other services, or from inadequate operation, either of the aircraft station, or of one or another of the ground stations, with which it is desired to communicate *en route*.

Here again these difficulties are outside the scope of the wireless company, and hence the supervision of the communication services as a whole, is a matter in which the Air Ministry, as being the competent government authority, actively participate.

Control is exercised in the case of British commercial aircraft communications through the medium of a small committee which meets at monthly intervals at the Air Port, under the Chairmanship of an Air Ministry representative, and which is attended by representatives of the Air Transport Company and the Wireless Company.

At these meetings each cause of ineffective working during the previous month is investigated and action agreed upon to reduce liability of recurrence.

The Air Ministry control and operate the ground station at the Air Port, which was installed by the Marconi Company, and hence, at these meetings, all the authorities responsible are duly represented.

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Such is the reliability of present-day aircraft wireless, that payment for 99 per cent. of the total hours and miles flown with wireless is by no means uncommon.

The Air Ministry exercise control in another way. It has to satisfy itself that the wireless apparatus will not in any way endanger the airworthiness of the aircraft in which it is installed. Apparatus is therefore "approved" as a type suitable for installation on a licensed aircraft.

FIG. 6.

Subsequently, all apparatus of the approved type must be inspected and passed by the Aeronautical Inspectorate Department of the Air Ministry, but in actual practice this responsibility is delegated by the Department to the Company in this way :—

After examination of the Company's organisation for inspection and test at the Chelmsford Works, and upon due consideration, the Air Ministry have placed the Company in the category of "approved firms," that is to say, the Air Ministry recognise the competency of the Company to inspect, test and pass its apparatus, prior to despatch, as on behalf of the Air Ministry.

Our Engineer-in-Charge at Croydon is also similarly empowered to act as on behalf of the Aeronautical Inspectorate Department, and in this way assumes official responsibility in seeing that only sound material is installed.

A description of the Marconi Company's organisation at the London Terminal Air Port would be incomplete without mention being made to one or two other activities which are centred there. Although the Company does not assume responsibility for the operation or maintenance of the ground station, it has always had a considerable and active technical interest in the ground station equipment.

In the earliest days the Company demonstrated the utility of the direction-finding receiver as an aid to aerial navigation, and when the Terminal Air Port of London was created it installed for the Air Ministry one of the first specially designed Air Port Wireless Stations to be built in the world.

The station, which was designed by Captain P. P. Eckersley, was a remotely-controlled 1½ kw. Telephone-Telegraph Station, operation being carried out from a direction-finding receiving station situated some distance away from the transmitter, and connected by landline to the aerodrome control tower.

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This station did good service for about 7 years, but has lately been replaced by a more modern, more complete and more powerful plant.

The new plant, which will be described in a subsequent issue, has now been working successfully for the last 18 months, and is shortly to be elaborated in order that the ever-growing needs of the service can be adequately provided for.

Lastly, the Marconi Aircraft Development Section of the Company is centred on this aerodrome.

Here is carried out experimental and testing work necessitated by the continual investigations which the Company undertakes into the many problems which have to be solved in producing new and advanced types of apparatus.

The Company maintains a specially-equipped van for carrying out range tests from point to point on the ground, whilst a " Bristol " Fighter aeroplane is used to confirm results in flight.

J. M. FURNIVAL.

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SHORT WAVE SIGNAL STRENGTH MEASURING APPARATUS—II

In the May Number of THE MARCONI REVIEW *a technical description was given of a Short Wave Signal Strength Measuring Set recently developed by the Marconi Company.*

The article concluded with an account of the methods used for calibrating such a set and showed how the performance of the attenuator used can be checked against the mutual inductance by which the auxiliary calibrating signal is introduced into the aerial.

IN the type of Signal Strength Measuring Set discussed in the present article, relatively large currents are used at the input end of the attenuator (50 to 100 milliamps.) and microamps. are required in the primary of the mutual, so that it is essential that the performance of the attenuator unit, where the reduction takes place, shall be accurately known.

For D.C. currents or low frequency alternating currents, a " T " network of resistances, Fig. 1, is a very suitable arrangement for reducing the known input *i* to a known fraction at the output, but difficulties arise if the arrangement is used at very high frequencies.

The chief difficulty is this : Owing to the capacity between input and output the voltage induced on B may, at sufficiently high frequencies, be large compared with the voltage at B, on account of the resistance drops in the various members of the network from which the performance is calculated. There is a spurious jump-over from A to B which is not calculable, and the attenuator in this form is useless.

The effect shows itself in a most marked manner if one of the series resistances is broken. According to calculation there should be no voltage at B, but actually B may have a large voltage induced in it by capacitative induction from A. Very perfect shielding between input and output is therefore necessary.

This has been achieved in the following design, which is illustrated in Fig. 2. Each unit of the " T " is in a separate screening box, as shown below, but the box cannot be completely screened, as there must be a connection from one box to the next. This connection is made through the brass tubes A and B by the 47 gauge Eureka wire placed axially in the tube.

The performance of such a resistance tube, as it may be called, can be accurately calculated even at the highest frequencies used.

Thus the potential drop down the tube is only dependent on the *Zi* drop along the wire where Z is the effective impedance of the wire, in particular if the wire is

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disconnected there is no potential jump-over from P to Q. This has been tested and found to be the case.

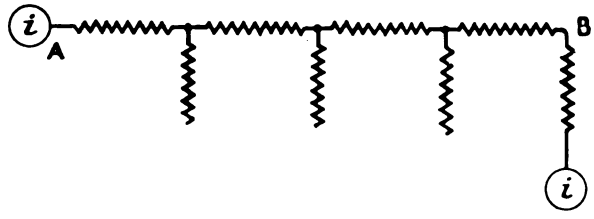

FIG. 1.

Thus there is no capacity jump-over from one box to the other and consequently from one end of the attenuating chain to the other.

Double screening is provided by the extra shielding box C, which is a sliding fit on to the two tubes A and B and into which the short resistance R_2 screws.

The performance of the attenuator can then be calculated from the filter formula

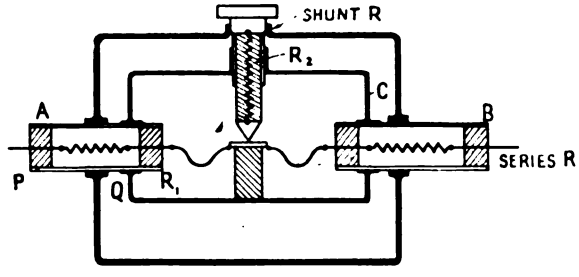

FIG. 2.

$$\cosh \alpha = \tfrac{1}{2}\frac{Z_1}{Z_2} + 1$$

where $e^{-\alpha}$ is the reduction per stage
Z_1 is the impedance of a series unit
and Z_2 that of a shunt unit.

The mean value of Z_1 is 10·448
,, ,, Z_2 is 2·957
which gives the mean attenuation per stage as 5·33.

There are four stages in the attenuator, numbered 1, 2, 3, 4 (Fig. 3), and since the resistances are not all equal the attenuation per stage is not quite the same for all stages. They are given in the following table, which is self-explanatory :—

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TABLE I.

Arrangements of Shunts. Out	In	I_o/I_i (Ratio of output to input current). I_o = output current of attenuator. I_i = input current of attenuator.	
A 1, 2, 3, 4	—	$\frac{1}{1}$	=1
B 1, 2, 3	4	$\frac{1}{5\cdot18}$	=0·193
C 1, 2	3, 4	$\frac{1}{5\cdot18\times5\cdot18}$	=0·0373
D 1	2, 3, 4	$\frac{1}{5\cdot18\times5\cdot18\times5\cdot26}$	=0·00708
E —	1, 2, 3, 4	$\frac{1}{5\cdot18\times5\cdot18\times5\cdot26\times5\cdot75}$	=0·001232

The total attenuation is 812/1.

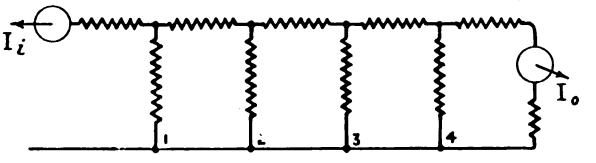

FIG. 3.

Attenuator Mutual Inductance Check.

The test may be followed with reference to the skeleton diagram below, and was arranged as follows (Fig. 4) :—

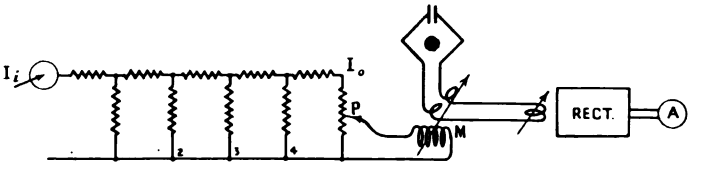

FIG. 4.

No. 1 shunt of the attenuator was removed. A convenient input current I_i was obtained on the required wavelength. The mutual M was adjusted to near the

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top of the scale with a value M_1, and the receiver was adjusted to give a measurable output A on the recording ammeter. Let the current in the primary of **M** be i_1.

Shunt No. 2 was then removed and the input current I_i and λ were adjusted to their previous values. Then according to calculation the output current I_o should be 5·26 times as great as previously (see table) and consequently the current in the primary of **M** i_2 should be increased in this ratio. Now leaving the receiver untouched, **M** was reduced until the same output current in **A** was recorded. Let this value of **M** be M_2.

Since the output in **A** is the same in both cases, $M_1\ i_1 = M_2\ i_2$, or $\frac{M_1}{M_2} = \frac{i_2}{i_1}$; but $\frac{i_2}{i_1}$ should be the calculated ratio for the attenuation of stage Z, *i.e.*, 5·26.

The results obtained on wavelengths down to 15**M**. are shown in the following table and curve. See Curve No. 1.

TABLE 2.

λ	I_i	Shunts In	M	Ratio
300	55 MA	2 3 4	·665	
				= 5·31
,,	,,	3 4	·125	
240	56	2 3 4	·6565	
				= 5·31
,,	,,	3 4	·1235	
100	82	2 3 4	·6555	
				= 5·35
,,	,,	3 4	·1225	
48	85	2 3 4	·6425	
				= 5·24
,,	,,	3 4	·1125	
30	62·5	2 3 4	·6475	
				= 5·35
,,	,,	3 4	·122	
20	56	2 3 4	·635	
				= 5·20
,,	,,	3 4	·122	
15	55	2 3 4	·656	
				= 5·33
,,	,,	3 4	·123	

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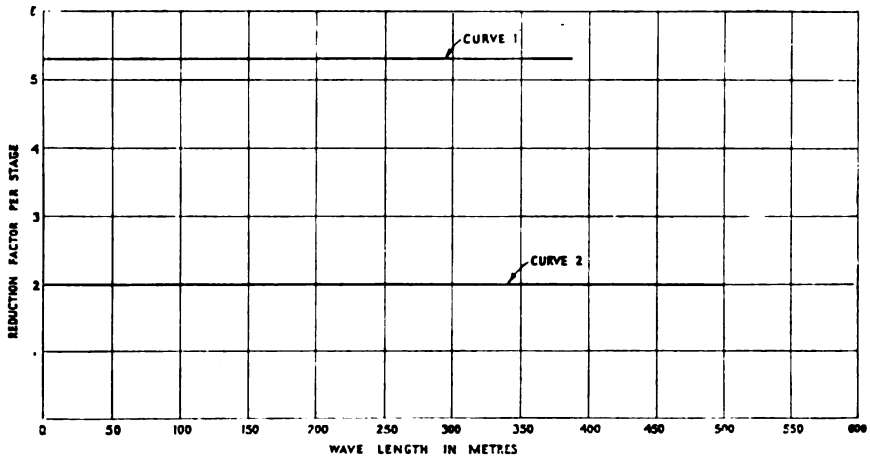
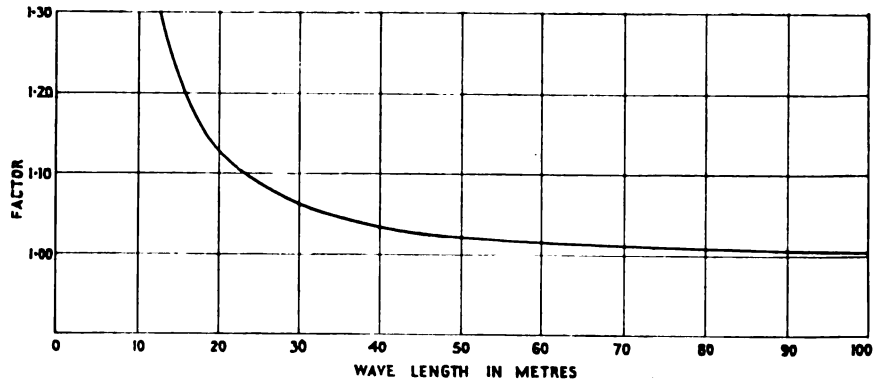


Curves i and ii. Internal calibration of Signal Measuring Set.



Curve iii. Correcting factor for Z potentiometer.

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TABLE 3.

λ	I_i	Potr	M.	Ratio
550	60	1	·61	
			———	= 1·92
,,	,,	2	·3175	
400	60	1	·6365	
			———	= 2·0
,,	,,	2	·3175	
250	55	1	·6325	
			———	= 1·98
,,	,,	2	·3195	
100	82	1	·6325	
			———	= 1·982
,,	,,	2	·3185	
48	65	1	·651	
			———	= 1·967
,,	,,	2	·3315	
20	56	1	·474	
			———	= 1·86
,,	,,	2	·260	
15	62	1	·622	
			———	= 1·896
,,	,,	2	·328	

The observed ratio even at the short wavelength is within the limits of experimental error of the calculated value, and seems to be a very satisfactory check of the attenuator and mutual inductances.

It is, of course, conceivable that the errors in M compensate those in the attenuator at some given wavelength, but that this should be the case on all the wavelengths tried seems almost inconceivable.

A further check is as follows: The potentiometer wire has two tappings, the resistances being respectively 0·982 and 1·847, with a ratio of 1·98. A similar test to the previous one was made, keeping the attenuator the same but varying the potentiometer tapping. The ratio of the M for constant receiver output should then be 1·98. The table and curves give the results, which are again within the limits of experimental error. (See Table 3. Curve No. ii.)

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Calculation of the voltage induced by the auxiliary oscillator.

If I is the input current in the milliammeter (Fig. 5)

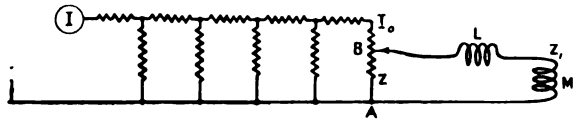

FIG. 5.

then $I_o = \frac{I}{k_1 \; k_1 \; - \; - \; - \; k_n}$ where k is the reduction factor for each stage (where I_o is the output current).

If we assume that the impedance Z_3 of the circuit consisting of the primary of the mutual and the choke L is very large compared with Z, then the voltage across AB is $\frac{Z\,I}{k_1 \; - \; - \; - \; k_n}$ (where Z is the impedance between A and B).

The current in the primary M is therefore $\frac{Z\,I}{k_1 \; - \; - \; - \; k_n} \cdot \frac{I}{Z_3}$ and the voltage induced in the frame aerial is $\frac{Z\,I}{k_1 \; - \; - \; - \; k_n} \; \frac{Mp}{Z_3}$, so that in addition to knowing $k_1 \; - \; - \; - \; k_n$ and M (which have been checked according to the tests described above), the values of $Z + Z_3$ must be known. (I is read direct from the milliammeter.)

The impedance Z of the potentiometer may be taken as equal to its resistances for wavelengths down to 60 metres. The potentiometer check test shows that it is at least proportional to the resistance. At very high frequencies the inductive drop down the wire becomes of the same order as the resistive drop. When the wire and return are concentric cylinders the inductance per unit length can be accurately calculated from the formula

$$L/\rho = 2 \log b/a$$

where a is the diameter of the wire and b is the internal diameter of the return tube. In this case it is 12·01 cm. per cm. of wire.

If R is the resistance of 1 cm. wire

$$Z^2 = R^2 + p^2L^2$$

$$Z = R\sqrt{1 + \frac{p^2L^2}{R^2}}$$

$$R = 2{\cdot}35 \text{ for No. 47 Eureka.}$$

Table 4 gives the correcting factor. This multiplied by R gives the effective Z at the corresponding frequency.

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The correction is negligible above 60M, but increases to 23 per cent. at 15m. The correcting factor is shown in Curve No. iii.

TABLE 4.

λ	$\frac{pL}{R}$	$\frac{pn^2}{R^2}$	$\sqrt{1+\frac{p^2L^2}{R^2}}$
100	·0107	0·01142	1·00571
80	·01338	0·01783	1·00801
60	0·1783	0·03180	1·0159
40	0·2575	0·0662	1·0331
30	0·3565	0·1275	1·0625
20	0·5356	0·2756	1·130
15	0·7120	0·5060	1·2270

It might at first be thought that this change in impedance of the resistance wires with frequency would invalidate the attenuator calculation, the same resistance wires being used in this as in the potentiometer, but it will be observed that the attenuation per stage represented by the formula

$$\cosh \alpha = \tfrac{1}{2}\frac{Z_1}{Z_2} + 1$$

only depends on the ratio of the impedance of the series and shunt arms of the attenuator, which remains constant however Z_1 and Z_2 may vary so long as the two arms are made of the same wire.

The attenuation per stage should therefore be independent of this frequency correction, and is actually found to be so.

The impedance Z_3.

Z_3 includes the calibrating choke and the primary of the mutual inductance. These can be measured by low frequency and high frequency methods. The small mutual which is used on the high frequency range is 11·65 mics. measured on low frequency and 11·75 mics. with the extra inductance of leads measured at about 100M. This last measurement was made by inserting a known calibrating condenser where the calibrating choke is usually placed and tuning the circuit beyond (Fig. 6).

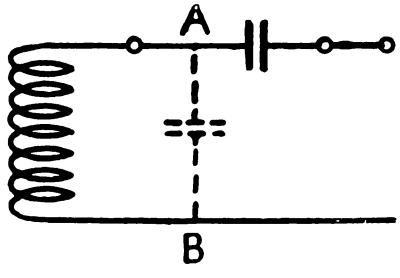

FIG. 6.

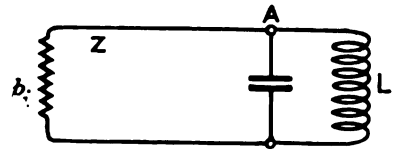

FIG. 7.

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At higher frequencies the effective impedance Z_3 increases on account of stray capacity across AB. Z_3 is then very nearly

$$\frac{jLp}{1 - p^2 LC}$$

where C is the stray capacity across AB.

But it must be observed that in the working condition which may be represented by Fig. 7, so long as the impedance Z_4 of the lead to A is small, the voltage $V = ZI_0$ is across L and the current through it is $\frac{V}{jpL}$ in spite of the presence of the stray capacity. In fact, on account of the increase in impedance of the circuit AL when resonance is approached, the drop down Z_4 will be reduced.

It is therefore accurate to specify the current in L as $\frac{ZI_0}{jpL}$, but it is important that the calibrating choke must not be inserted for waves below 100M (where the stray capacity begins to be effective), as this would make Z_4 large.

T. L. ECKERSLEY.

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THE USE OF SHORT WAVES FOR LONG DISTANCE COMMUNICATION

The following article is an attempt to recapitulate, very briefly, some of the most salient features of long distance Short Wave transmission.

The subject is discussed under the following headings :—

(1) *The extent of the Short Wave frequency spectrum.*

(2) *Conditions under which short wave communication over long distance is possible.*

(3) *Effect of light and darkness on various wavelengths.*

(4) *Allocation of wavelengths.*

FOR the purposes of discussion, the short wave, or high frequency spectrum may be considered as embracing all wavelengths between 100 metres and zero, or frequencies of between 3,000 kilocycles and infinity. In practice, however, this band may be considerably reduced.

The upper limit of wavelength is fairly definitely fixed, for we know that if the behaviour of the wave propagation is to conform to the usually accepted short wave theories, *i.e.*, to the generally accepted theories of ionic refraction in the upper ionised layers of the atmosphere, the conditioning factor is that the electrons can make many oscillations in the time between collisions with the molecules of the atmosphere.

It has been shown that this mean time at heights above 80 km. is greater than about 3×10^{-7} sec., from which it can be seen that ionic refraction effects are limited to wavelengths $\lambda < 100$ m.

As regards the lower limit, we may, for present purposes, fix this as being somewhere in the neighbourhood of 8·6 metres, this being the value given by Mr. T. L. Eckersley for the short wave day limit for long distance communication.

The frequency band to be considered on the above assumptions extends from 3,000 kilocycles to 34,880 kilocycles, *i.e.*, there is a spectrum of nearly 32,000 kilocycles available for short wave working.

Now the two necessary conditions for satisfactory long distance radio communication are :—

(1) The waves should be bent sufficiently round the curvature of the earth, *i.e.*, they should suffer sufficient refraction in the ionised layers, and should not pass through them.

(2) The attenuation experienced by the waves should be small.

If we consider (1) first, it can be shewn that a definite value of $\lambda_{min.}$, where this is the value of the shortest wave that will be sufficiently bent to come down to earth, will be given by the expression :—

$$\lambda^2_{min.} = 2h\pi m/RNe^2$$

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where h = height corresponding to a density N ;
m = mass of electron ;
e = charge of electron.

The value of h/N, which is really the deciding factor of the above expression, will, of course, alter according to the degree of light and dark prevailing at the time, but definite values can be given to it for fixed conditions, and from these the minimum wavelength which can be used for these conditions can be found. It must be understood, however, that the wavelength found in this manner is not necessarily the best as regards small attenuation. Different wavelengths experience different attenuations under differing degrees of light and darkness through which they pass. In a recent paper issued by the Marconi Company, a series of empirical curves are given, which can be used to obtain the signal strength of a station of known power at various distances under different degrees of light, for various wavelengths. These curves will, it is hoped, prove very useful in predetermining the wavelength of a station over any route at any time.

A table, giving the approximate distances in miles at which signals cease to be audible at different wavelengths assuming a transmitter of approximately 10 kw. power is given below.

These figures are for intense daylight routes, and refer to the use of a simple receiver at the receiving end.

Wavelength in metres.	Distance in miles.
15	12,000
20	7,000
25	4,500
30	3,000
40	1,500
50	900

For a route entirely in twilight, the attentuation on all wavelengths is greatly reduced. Signals on wavelengths of the order of from 15 to 30 metres will generally be found to be the best for use on such a route.

The attenuation of wavelengths above 40 metres is slight under conditions of complete darkness. On wavelengths below about 20 metres, signals are reduced, due probably to the fact that the ray is insufficiently bent.

From the above summary, it will be seen that considerable care must be taken before a wavelength can be allocated to any route from the point of view of obtaining minimum attenuation. Another problem has arisen of late years which threatens to become very serious. This is the crowding of the frequency spectrum by the

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EXTRACT FROM RADIOTELEGRAPH REGULATIONS, WASHINGTON, 1927, *re* ALLOCATION OF WAVELENGTHS ON SHORT WAVES.

Frequencies in kilocycles per second (kc./s).	Approximate Wavelengths in Metres.	Services.
2,850– 3,500	105–85	Mobile services and fixed services.
3,500– 4,000	85–75	Mobile services. Fixed services. Amateurs.
4,000– 5,500	75–54	Mobile services and fixed services.
5,500– 5,700	54–52.7	Mobile services.
5,700– 6,000	52·7 –50	Fixed services.
6,000– 6,150	50 –48·8	Broadcasting.
6,150– 6,675	48·8 –45	Mobile services.
6,675– 7,000	45 –42·8	Fixed services.
7,000– 7,300	42·8 –41	Amateurs.
7,300– 8,200	41 –36·6	Fixed services.
8,200– 8,550	36·6 –35·1	Mobile services.
8,550– 8,900	35·1 –33·7	Mobile services and fixed services.
8,900– 9,500	33·7 –31·6	Fixed services.
9,500– 9,600	31·6 –31·2	Broadcasting.
9,600–11,000	31·2 27·3	Fixed services.
11,000–11,400	27·3 –26·3	Mobile services.
11,400–11,700	26·3 –25·6	Fixed services.
11,700–11,900	25·6 –25·2	Broadcasting.
11,900–12,300	25·2 –24·4	Fixed services.
12,300–12,825	24·4 –23·4	Mobile services.
12,825–13,350	23·4 –22·4	Mobile services and fixed services.
13,350–14,000	22·4 –21·4	Fixed services.
14,000–14,400	21·4 –20·8	Amateurs.
14,400–15,100	20·8 –19·85	Fixed services.
15,100–15,350	19·85–19·55	Broadcasting.
15,350–16,400	19·55–18·3	Fixed services.
16,400–17,100	18·3 –17·5	Mobile services.
17,100–17,750	17·5 –16·9	Mobile services and fixed services.
17,750–17,800	16·9 –16·85	Broadcasting.
17,800–21,450	16·85–14	Fixed services.
21,450–21,550	14 –13·9	Broadcasting.
21,550–22,300	13·9 –13·45	Mobile services.
22,300–23,000	13·45–13·1	Mobile services and fixed services.
23,000–28,000	13·1 –10·7	Not reserved.
28,000–30,000	10·7 –10	Amateurs and experiments.
30,000–56,000	10 – 5·35	Not reserved.
56,000–60,000	5·35–5	Amateurs and experiments.
Above 60,000	Below 5	Not reserved.

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continually increasing number of stations which are working on the short wave band. The partial solution of this problem has been attempted by the various International Conferences which have been called from time to time. An extract from the Washington Conference of 1929 is given above, which attempts to allocate specific wavelengths for definite purposes.

In this extract, all commercial land stations are included under the heading of fixed services. Ship stations, etc., are included in mobile services, and certain wavelengths are allocated to broadcasting stations and for amateur use.

At a Conference held at Ottawa in January, 1929, between the representatives of the United States and Canada, the following decision was reached :—

> " A channel shall be regarded as a band of frequencies, the width of which progresses numerically from the lower to the higher frequencies as shown in the following table :—

Frequency (K/C)	Channel Width (K/C)
1,500—2,198	4
2,200—3,313	6
3,316—4,400	8
4,405—5,490	10
5,495—6,000	15

> " The Governments agree to adopt for the present in their National plan of allocation a separation of 0·2 per cent. between radio frequency channels, and to permit stations under their respective jurisdiction to occupy the assigned frequency and the adjacent frequencies to the limit permitted by the frequency maintenance tolerances and necessitated by the type of emission the station may be authorised to use.
>
> " For commercial telephony, a band width of six kilocycles shall be permitted.
>
> " For the present, a 100 kilocycle band width shall be considered standard for television."

The whole question is, however, under review at the " Comité Consultatif International Technique des Communications Radioélectriques " being held at The Hague at the present time.

Another limitation to the number of communication channels available on the short waves is the lack of perfect constancy on the part of the station frequency. A very small variation of this frequency is sufficient to cause one station to invade the frequency limits of another.

The practical limit at present is just about sufficient to enable consecutive stations to work if great care is taken on the part of the station operator. This accuracy may be expected to increase later when improved apparatus is put into use at the less efficient stations.

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A SHORT WAVE PORTABLE MILITARY TRANSMITTER

TYPE Z.S.A.3

The essential features of a military wireless station are :—

(1) *That it should be extremely simple to operate and simple in design ;*

(2) *That it should be light and easily portable.*

A full consideration of these conditions has led the Marconi Company to produce two distinct types of portable stations. These are :—

(A) *The X, Y and Z series in which the transmitting and receiving circuits are contained in one or two cabinets.*

(B) *The U series in which the apparatus is divided into several units of more or less open construction.*

The former are specially suitable for temporary or permanent installation in any suitable type of vehicle which may be obtainable, the prefix X denoting a telephone, Y a telegraph and telephone, and Z a telegraph set, while the latter are intended for permanent installation in a chassis specially equipped for the purpose.

The stations of the " U " type are, in general, more flexible and powerful than those of the " X," " Y " and " Z " type.

One of the most recent of the " Z " type of transmitter, the Z.S.A.3 is described below.

THE Z.S.A.3 is a small, portable, short-wave transmitter, extremely simple in design, and intended for use, in conjunction with the Z.S.A.2 receiver, as a military transmitter on a spot wave length of 30 metres.

Power is supplied to the set by means of a hand-driven generator, with an output of 800 volts at 65 m α for the high tension supply to the D.E.T.1 valve used in the transmitter, and of 7 volts 2 α for the filament lighting.

The diagram of connections of the transmitter is shown below (Fig. 1).

It will be seen from this that provision is made only for continuous wave signalling. This is achieved by breaking the grid circuit of the valve and the negative of the high tension supply, together from the filament.

The circuit is of the ordinary bottom feed fundamental type, the coil " A " representing the inductance in the oscillatory circuit. No capacity, other than that existing in the valve itself, is provided in the closed circuit.

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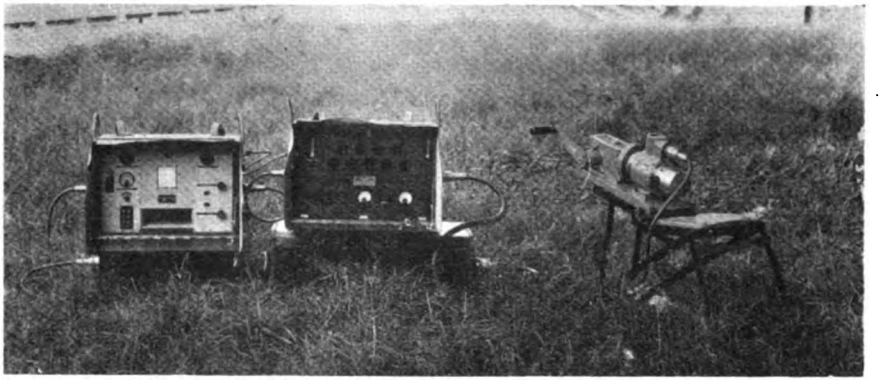
The high tension supply is taken through a fixed tapping on the inductance "A" and reaches the anode through another tap which is adjustable. The grid of the valve is taken through a blocking condenser to an adjustable tap on the side of the inductance remote from the anode tap.



The valve used as the oscillator is a D.E.T.1.S.W. This has a maximum continuous anode dissipation of 40 watts, a voltage magnification factor of 8·5, and

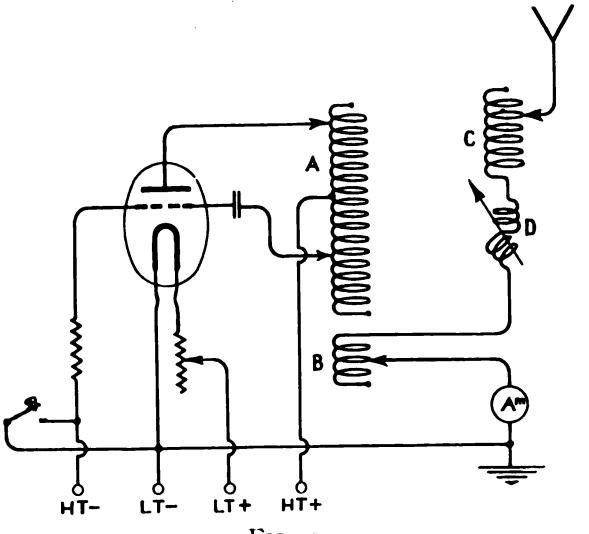


FIG. 1.

a value of R_p of 5,000 w. It is designed to have a very small internal grid-anode capacity, the anode and grid being taken out at opposite ends of the valve.

A ·001 by-pass condenser is also provided between H.T. and earth, to render the impedance of the H.T. generator negligible as regards high frequency currents.

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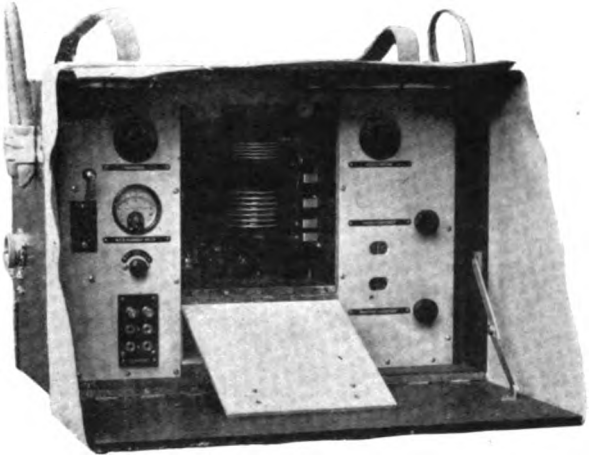
The aerial circuit is magnetically coupled to the closed circuit, and consists of a loading coil, a variometer, a coupling coil and aerial ammeter, all in series. The coupling coil serves to couple into the closed circuit, and the variometer serves



as a fine adjustment of wavelength. The tappings on both the coupling and loading coils are adjustable.

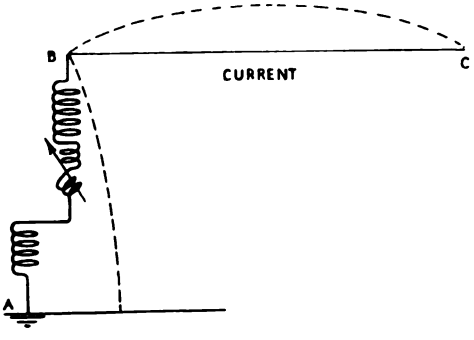


FIG. 2.

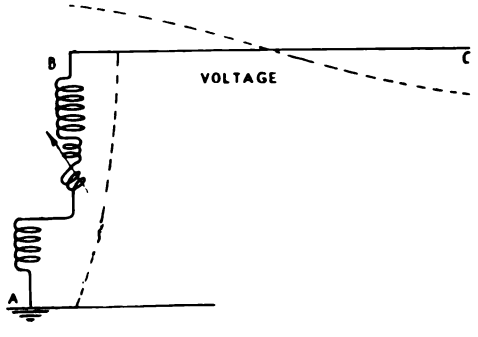


FIG. 3.

The closed circuit consists of 18 turns of No. 10 copper wire wound on porcelain slats supported on a wooden former. The coupling coil is wound over the closed circuit coil, and is spaced $\frac{3}{8}$ inches from it. It consists of 3 turns of wire. The aerial coil has 20 turns of No. 10 copper wire wound on a 3-inch former and the variometer is wound on a spherical wood former and consists of $4\frac{1}{2}$ turns of No. 10 copper wire.

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The transmitter radiates on a half-wave aerial, the aerial circuit of the transmitter loading the entire aerial system to $\frac{3}{4}$ of a wavelength.

In this case the current and voltage curves are given above (Figs. 2 and 3).

In each of these figures the aerial circuit of the transmitter is represented from A to B, and the aerial proper from B to C.

The transmitter is provided with one earth, for the closed circuit and filament and for the aerial and aerial circuit. This consists of two brass or copper rods driven into the ground and connected to the common earth lead.

The receiver intended to be used in conjunction with the set is that supplied for use also with the Z.S.A.2 set. The receiver circuit is a simple detector and oscillator followed by two note magnifiers. A detailed description of the receiver will, however, be given later with the description of the Z.S.B.2 transmitter.

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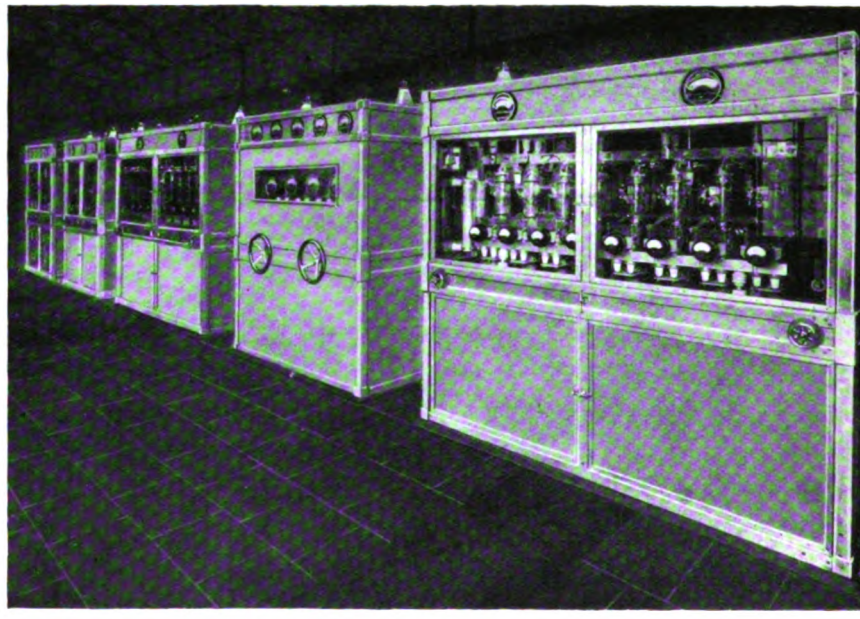
MARCONI NEWS AND NOTES

MARCONI BROADCASTING INSTALLATIONS



Marconi 50 kw. high-power broadcasting transmitter, Type P.B.

The New British Regional Stations.

The British Broadcasting Corporation announced on September 14th, that the new London regional broadcasting station at Brookman's Park would begin its preliminary test transmissions on September 16th, on 2 LO's normal wavelength of 365·3 metres (342 kh.) after the close of the ordinary London daily programme.

The British Broadcasting Corporation's announcement proceeds :—

" Primarily designed for the provision of an alternative programme service this station consists of two separate high-power transmitters. The alternative programme, however, will not be introduced until such time as listeners have become accustomed to receiving the single programme from the new station.

" The schedule of preliminary transmissions will be as follows :—

" Starting on Monday night a few minutes after the close of the London programme, there will be test transmissions of music for one hour every night for a fortnight, excluding Sundays.

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"On and after Monday, September 30th, the last section of the London programme, which is usually dance music, will be transmitted from the new station every night for two or three weeks, excluding Sundays.

"Notice will be given later of the date on which Brookman's Park will take over the entire service."

The Marconi Company's part in the New Service.

The new regional broadcasting transmitters at Brookman's Park have been manufactured, in accordance with the special requirements of the British Broadcasting Corporation, by Marconi's Wireless Telegraph Company Limited, and therefore represent the highest standard in the manufacture of wireless broadcasting apparatus.

Marconi broadcasting transmitters are accepted throughout the world as being of the highest standard of design and performance as is shown by the fact that broadcasting installations manufactured by the Marconi Company and its affiliated companies are in service in the following countries :—

Australia.	Czecho-Slovakia.	Jugo-Slavia.	Russia.
Austria.	Great Britain.	Korea.	South Africa.
Belgium.	India.	Norway.	Spain.
Brazil.	Irish Free State.	Peru.	Sweden.
Canada.	Italy.	Poland.	Switzerland.
China.	Japan.	Roumania.	Etc., etc.

Other Important Broadcasting Developments—Iceland.

During the month the Marconi Company has been associated with other important developments in broadcasting in various parts of the world.

The announcement was made on September 13th, that the Marconi Company had obtained from the Iceland Government a contract for the first broadcasting station to be erected in Iceland.

This station will be situated at Reykjavic, the capital of the island, and is to be completed in time for the thousandth anniversary of the discovery of Iceland, which will be celebrated in June next year.

The transmitter will be of a new design based on the wide experience of the Marconi Company which, as shown above, has supplied wireless broadcasting stations for service in over twenty countries. It will have a power of 15 kw. in the aerial and will work on a wavelength of about 1,200 metres.

Special circuits will be incorporated to enable it to be used for telegraph transmission as well as broadcasting. This will enable the station to be used for meteorological services.

Meteorological information from Iceland is of great importance in forecasting weather conditions for Europe and the Atlantic. The power of the new station which the Marconi Company is building, will enable reports from

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Iceland to be received over a wide area. It will thus form an important addition to the meteorological services.

Poland.

The Marconi Company has also been successful in obtaining the order for a large extension of the Polish Broadcasting organisation. This order is for six transmitters and forms one of the largest orders given in recent years in connection with broadcasting services. Following the English example, the Polish Broadcasting organisation is to be remodelled so as to provide alternative programmes.

The new equipment will comprise one 120 kw. aerial input broadcasting transmitter with full modulation, two high-power regional stations with 16 kw. aerial input, and three local relay stations.

The new installations will be of the most modern and up-to-date type both as regards technique and design.

Provision will be made for simultaneous reception throughout the whole of Poland, the relay stations transmitting on a common wavelength employing the tuning fork system of control, such as is in successful operation in Great Britain.

In addition to the simultaneous broadcasting of programmes throughout Poland, arrangements will be made for the transmission of high-class Polish programmes to foreign countries.

The 120 kw. station will be situated near Warsaw, and will be used in addition to the 12 kw. Marconi Station which is already giving such an excellent service at Warsaw and has been in operation there since 1927.

The new high power station will take the wavelength of the present 12 kw. station, which is 1,411 metres, and the 12 kw. station will work on a lower wavelength. The two stations will be employed simultaneously for the transmission of alternative programmes.

The two new 16 kw. stations will be situated at Lemberg and Vilna to provide programmes for the areas outside the range of the lower-powered station at Warsaw.

Of the three local relay stations, one will be situated at Lodz, the Polish Manchester, 80 kilometres from Warsaw. The provision of this station is interesting seeing that it is for the definite purpose of providing an alternative crystal programme for a working-class district.

The Marconi Company is entrusted with the supply of everything connected with these stations, including all constructional services. The whole of the technical resources of the Company will be concentrated in carrying out the scheme.

When the work is completed it is confidently anticipated that Poland will possess one of the most modern and the most efficient broadcasting services in the

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world, providing alternative programmes available to users of crystal and valve receivers over the greater part of the country.

Arrangements are being made for alternative programmes to be available from Warsaw before the end of this year, and the whole scheme is expected to be in operation before the end of 1930.

5,000 mile range of a Marconi Broadcasting Station.

Reports are constantly being received of the excellent range and quality of the transmissions from the Marconi broadcasting stations throughout the world. The latest report from the *Cape Argus*, of August 17th, gives interesting particulars with regard to the reception in South Africa of the Marconi station at Bratislava in Czecho-Slovakia.

This station is a Marconi 12 kw. broadcasting transmitter, type P.A.5, employing the principle of low-power modulation. Its wavelength is 278·8 metres (1·80 kh.), and among its special features is the half wavelength aerial. Bratislava is about 5,000 miles from Cape Town, where, according to the *Cape Argus*, a number of listeners are getting excellent reception.

Empire and the Schneider Trophy Races.

Not only was the British Broadcasting Corporation's description of the Schneider Trophy Race broadcast to English listeners, but it was also transmitted for the benefit of other countries through the short wave experimental station 5SW at the Marconi Works at Chelmsford, and reports have been received of excellent reception of this programme in Canada, the United States, and Australia, among other places.

In the United States, the transmission was relayed from more than twenty stations associated with the National Broadcasting Company. Engineers stated that the quality of the transmission was better than on any previous occasion and they were surprised at its exceptional clearness and quality.

Stockbroking at Sea.

Stockbroking on board ship has made the latest demands on the wireless service at sea, and the Marconi International Marine Communication Company has provided wireless apparatus to meet the very exacting conditions of this service on the ships of the White Star Line. Special Marconi short wave apparatus ensures direct and instantaneous communication with New York even when the ship is off the British coast, and enables business men in mid-Atlantic to take advantage of the speed and directness of wireless communication to transact highly important financial affairs with the greatest facility as well as certainty.

The following account of this achievement has been taken from the London newspaper, the *Daily News*, of September 10th :—

"A remarkable technical wireless achievement lies behind the successful operation of the Stock Exchange service on the White Star liner 'Majestic,' by

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Stockbroking office in White Star Liner "Majestic"—the largest ship in the world—where every fluctuation in 80 stocks quoted on the New York Stock Exchange may be seen on the board during New York business hours.

which the broker's office on board is linked with the Stock Exchange in Wall Street, New York.

"The tremendous difficulties of working an independent Duplex wireless service within a few yards of the ship's main transmitting installation were tackled by experts of the Marconi International Marine Communication Company, and completely overcome by the use of special screened aerials for each set.

"The ordinary telegraph service between ship and shore can be carried on as usual without in any way interfering with, or being interfered with by the special brokerage service which is working in a nearby cabin.

Four Operators Busy.

"The main Marconi installation of the 'Majestic' used for the normal wireless services consists of a 2 kw. valve transmitter with a receiver and direction-finder.

"Messages are transmitted principally on the wavelengths of 600 metres and between 2,100 and 2,400 metres. An enormous volume of traffic—sufficient to keep four operators hard at work—is handled throughout each voyage, in addition to official navigation and press messages.

"For the brokerage service a separate cabin has been equipped with a Marconi short wave transmitter and receiver for communication with the Louisburg (Canada). Tuckerton (U.S.A.), and Portishead (Wiltshire), radio stations, on 23 metres.

"In addition, a long wave receiver is used to pick up the special brokerage messages from Rugby Radio on 18,750 metres.

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" The special design and arrangement of the aerial system are such that the two wireless cabins are completely screened from each other, and no interference occurs between them whatever.

Speedy Business.

" As a result of this installation, business men travelling on the Atlantic can keep in touch with the movements of stocks and shares in which they are interested, and can continue their dealings almost as rapidly as from their offices ashore.

" The reply to the first brokerage message from the ' Majestic ' asking for a special stock quotation was in the hands of the passenger concerned within 2½ minutes after he had handed in his request at the broker's office on board.

" The rapidity and facility with which actual business can be transacted from mid-Atlantic were praised by Mr. Harry V. Dougherty, a United States business man, who said he asked for a bid and offer on Air Reduction Shares, and received a reply from the newly-opened brokerage office in exactly seven minutes."

Ship-to-Shore Telephony.

Attention has recently been directed again to the subject of wireless telephony as a means of communication between ships at sea and telephone subscribers ashore, and the growth in recent years of what may be termed " the international telephone habit " may now lead to the extension of telephone facilities to liners at sea.

The Marconi Company was a pioneer in this phase of wireless communication and its records show that the Company has for a number of years realised that the rapid progress of communication facilities to all parts of the world will eventually lead to a public demand for marine telephone services.

A Record of Achievement.

The Rt. Hon. F. G. Kellaway, P.C., Chairman of the Marconi International Marine Communication Company, in a recent letter widely quoted in the Press, drew attention to the following achievements of the Marconi engineers in ship-to-shore and ship-to-ship telephone communications :—

> " In the summer of 1920, when the Imperial Press Conference was held in Canada, wireless telephone conversations took place by means of Marconi installations between the delegates travelling from England on the S.S. ' Victorian ' and Poldhu and Chelmsford in England and St. Johns, Newfoundland, over distances exceeding 1,000 miles.
>
> " In May, 1923, a wireless telephone transmitter was installed on board the S.S. ' Olympic ' of the White Star Line, and good clear speech from the ' Olympic ' at sea was received on the ' Celtic,' which was then in New York harbour.

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"In August, 1923, the Marconi Company fitted a wireless telephone installation on the S.S. 'Lorina,' belonging to the Southern Railway Company. Good clear speech was maintained both ways between Marconi House and the 'Lorina' while crossing the Channel. This was the first direct conversation between passengers on a ship at sea and an ordinary telephone subscriber on land in England, as distinct from a telephone conversation between a wireless station on board a ship and a wireless station on land, or between two ships at sea.

"In February, 1925, the Marconi Company installed duplex wireless telephone apparatus on the S.S. 'Princess Ena,' belonging to the Southern Railway Company, and good speech was maintained between the 'Princess Ena' when crossing the Channel and telephone subscribers in London, Glasgow, Leeds, Cardiff, Bristol, Portsmouth, Southampton and Bournemouth. This installation was subsequently dismantled as the owners found that the demand for the facilities did not justify the cost.

Telephoning over the Arctic Circle.

"In January, 1927," Mr. Kellaway continued, "telephone communication was carried on over the Arctic Circle at distances of 600 miles and 1,100 miles, between the Hudson Bay Company's ships 'Bayrupert,' 'Baymaud,' and 'Baychimo,' by means of Marconi wireless telephone apparatus.

"In England over 30 Marconi wireless telephone stations are in constant use between the Lightships, Lighthouses and Shore Stations of Trinity House, the Mersey Docks and Harbour Board, the Dundee Harbour Trust and the Northern Lighthouse Board, while a number of similar wireless telephone stations have been installed for other Port Authorities in different parts of the world.

"The technical problem of establishing a telephone service between ships' passengers and telephone subscribers in any part of the United Kingdom was solved by the Marconi Company several years ago and such a service can be established whenever shipowners desire to instal the necessary equipment and a suitable wireless receiving station is available in this country."

Telephony between Ships.

In the same way, the Marconi Company is able to provide facilities for passengers to telephone from one ship to another. On this subject Mr. Kellaway wrote :—

"I would remind your readers that telephony between ships at sea has been in regular and growing use during the past three years. This Company has fitted wireless telephone installations on forty whalers operating in the Antarctic. These installations are from 100 to 500 watts power and give a normal range under favourable conditions up to 500 miles."

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No. 13

THE MARCONI REVIEW

October, 1929

CONTENTS

A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS—IV. PART II - - - - - PAGE 1

AN AIRCRAFT DIRECTION FINDER TYPE A.D.16 „ 10

COMMERCIAL SHORT WAVE WIRELESS COMMUNICATIONS. I—THE EMPIRADIO BEAM SERVICES - - - - - - - „ 14

MARCONI NEWS AND NOTES—
WIRELESS FOR ANTARCTIC EXPLORATION- „ 31

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD.

Marconi House, Strand, London, W.C. 2

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THE MARCONI REVIEW

No. 13. *October, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS—IV

PART II.—SOME USES OF THE SYNTHESIS MODEL, IN PARTICULAR THOSE RELATING TO WIRELESS PRACTICE

This article was commenced in the June number of THE MARCONI REVIEW. *In the following Section the phenomenon of Beats is discussed, and the methods of using the synthesis model to investigate this and allied phenomena are given. The article concludes with a brief discussion of "Push-Pull" circuits and the Synthesis of Alternate Current waveforms.*

Section 3—Mechanical Investigation of the Phenomenon of Beats particularly as it concerns envelope shape.

WHEN a transmitting station signals a continuous wave chopped up by morse signals, the receiving station would, if it received these signals as sent, get only a succession of clicks and although the intelligence is being conveyed, this type of signal would be very unsatisfactory for aural reception. The receiving station can, however, impress its own note modulation by adding a local continuous oscillator, so adjusted as to beat with the incoming signal and produce an audio frequency envelop, which, when rectified will give a convenient aural signal to the receiver; or beats at a supersonic frequency can be obtained if it is desired to create a change of high frequency for the purpose of gaining greater selectivity or amplification. The phenomenon of beats has, of course, been known for a very long time, and considerably investigated by students of sound, and it is suggested that certain erroneous ideas may have resulted from studying this phenomenon with the aid of musical notes, if one can judge by popular statements as to their composition.

The following quotation regarding this phenomenon represents an often accepted idea of the meaning of musical beats:—

> "When two notes differing slightly in frequency are produced at the same time, a throbbing sound or 'beat' is heard at regular intervals depending upon the difference in frequency of the two sources. Thus, if

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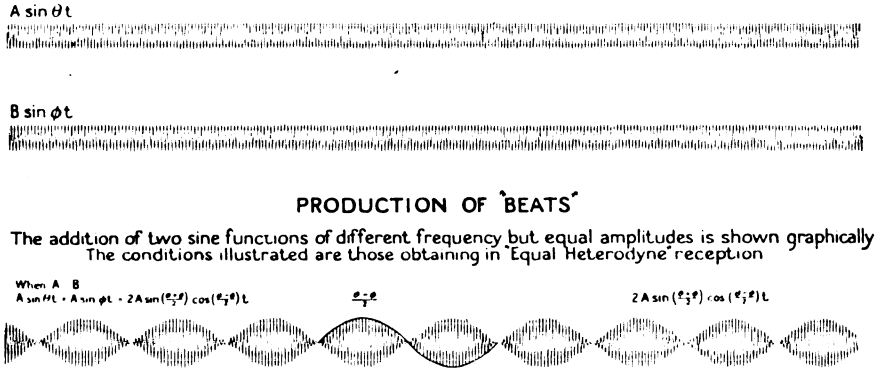
two tuning forks with periods of 1,000 and 1,002. per second are made to vibrate, beats will be heard at the rate of two per second. If the detuning is still greater the beats become so rapid that they produce a musical note or combination tone ; for instance, two notes with frequencies of 1,000 and 1,200 would give rise to a note with a frequency of 200."

Such a statement gives the erroneous idea that the beat, when it lies within the aural frequency band can be heard, but this is not a fact, for the beat is merely a throbbing due to a changing envelope amplitude, and no sound can possibly be


A sin θ t
B sin φ t
PRODUCTION OF "BEATS"
The addition of two sine functions of different frequency but equal amplitudes is shown graphically
The conditions illustrated are those obtaining in "Equal Heterodyne" reception
When A B
2A sin (φ+θ/2) cos (φ−θ/2)t

detected unless a rectifier is included in circuit. This may be seen by studying the records of Figs. 21 and 22, regarding which the following comments are made.

General Study of Beat Phenomenon.

The phenomenon is studied by adding two frequencies differing by a very small percentage, and although of course, the frequencies used with the model are low frequencies, it will be seen that since the beat envelope obtained is dependent upon difference of frequency, we can make this beat envelope of as low a value as we desire, whether low or high frequencies are being considered.

BEATS. (1) *The sum of two different frequencies,* very closely approximating.

(A) *Of Equal Amplitude.*

$$Ft = A \sin \phi t + A \sin \theta t$$

$$= 2 A \sin \frac{(\phi + \theta)}{2} t. \quad \mathrm{Cos} \frac{(\phi - \theta)}{2} t$$

The wave resulting from the addition of two such frequencies is seen from Fig. 21 to be a wave of one definite frequency varying in amplitude.

The resultant wave is of definite frequency $\frac{\phi + \theta}{2}$ rising and falling in amplitude,

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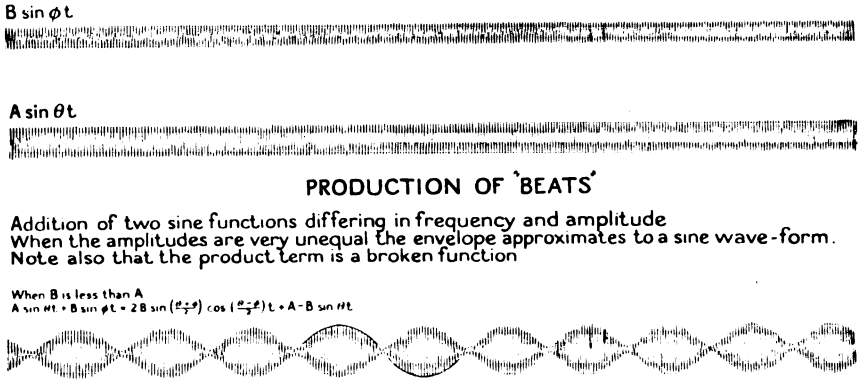
and it is to be noted that the rise and fall, *i.e.*, the beat, occurs once for every *Half Cycle* of the second product term. The second product term shown dotted is symmetrical about the zero line, its sinusoidal variation being at a frequency of $\frac{\phi - \theta}{2}$. The beat frequency, however, is the frequency of the rectified envelope and as the change occurs at every *Half Cycle* of the product term, its frequency will be $\phi - \theta$, and not $\frac{\phi - \theta}{2}$.


B sin φt
A sin θt
PRODUCTION OF 'BEATS'
Addition of two sine functions differing in frequency and amplitude
When the amplitudes are very unequal the envelope approximates to a sine wave-form.
Note also that the product term is a broken function
When B is less than A
A sin Θt + B sin φt = 2B sin (θ+φ/2) cos (θ−φ/2) t + A−B sin Θt

In order to be able to take out such a beat, no matter whether the frequencies are audio or high frequency, it is essential to rectify, as otherwise the mean value is still zero. It is observed that the envelope is not a sine wave in character, and although the form of equation for the rectified envelope can be obtained mathematically it does not appear to be a simple function.

Notice that the amplitude of the beat wave varies between 2 A (*i.e.*, the sum of the amplitude of the two waves) and zero, and this variation represents the strength of the received aural signal if rectification is carried out, and if the beat frequency lies within the aural band.

(B) *Of Unequal Amplitude.*

$A \sin \phi t + B \sin \theta t$ Where A and B are unequal and B say, is greater than A. Frequency values as before.

$$= 2A \sin \frac{(\phi + \theta)}{2} t. \quad \text{Cos} \frac{(\phi - \theta)}{2} t + (B - A) \sin \theta t$$

In this case the resulting frequency and the beat frequency remain unaltered as they are determined by the relative frequencies beating together and, therefore,

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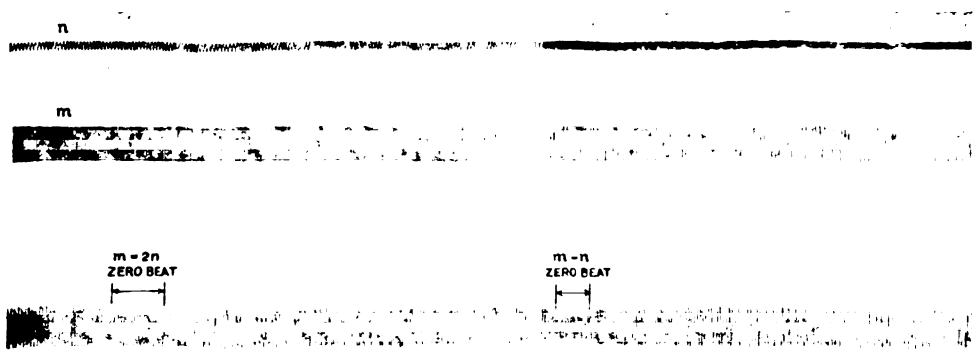

FIG. 23. *Diagram showing the beating of two waves, the frequency of one being kept frequency of the first to one quarter of the frequency of the first. n—smaller*

they will be unaffected by the respective amplitudes of the original waves as is seen from Fig. 22.

The second product term can still be traced, now as a broken function, but it should be noted that the change of amplitude will no longer equal the sum of the amplitudes but only twice the amplitude of the smaller beating wave. Thus in this case an equivalent D.C. component has been added of amplitude B — A as shown by the third term above, which would not affect the receiver telephone after rectification.

This means that if a small amplitude continuous wave signal is being received, maximum aural signal will be obtained, theoretically, when the local oscillator is equal in amplitude to the incoming signal, any excess of oscillator amplitude merely contributing to an equivalent D.C. component. Actually in practice rather greater local oscillator amplitude is required as the characteristic of a wireless rectifier is not perfect, but has a law which tends to be more nearly a square law.

Another apparent change is that although the frequency of the beat remains the same whatever the amplitudes of the frequencies, the rectified envelope may be considerably altered in character. For as the difference between the amplitudes increases, the rectified waveform appears to approach more nearly to the sinusoidal, and considering the extreme case, that is when the amplitude of one wave is infinitely great compared to the other the resulting beat becomes a pure sine wave of zero amplitude. This means in the case of W/T reception by beat that the character of the received signal changes as the strength of the local oscillator is altered.

As the local oscillator amplitude is increased, the signal wave shape approaches the sinusoidal, but should the two waves be of similar amplitude considerable

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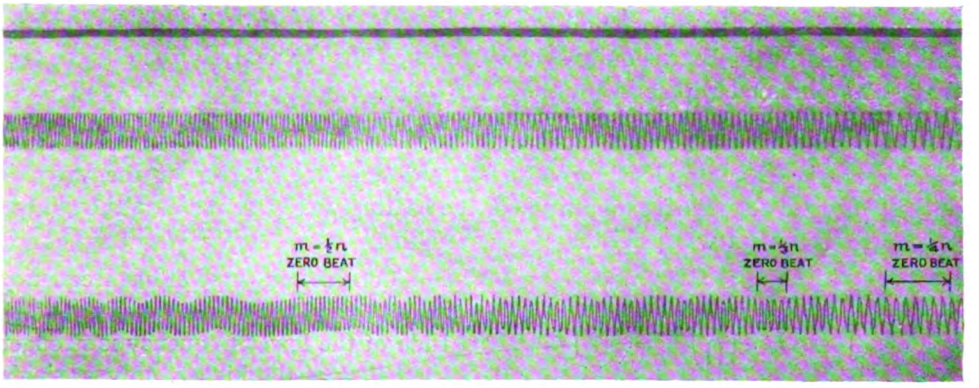

constant, and the frequency of the other being varied between limits of about twice the amplitude, constant frequency. m—lower amplitude, varying frequency.

envelope distortion will be evident. This distortion is entirely distinct from that produced from rectification, although a square law type rectifier will tend to exaggerate the effect.

Beats at Harmonic Frequencies.

Besides the production of beats when two frequencies closely approximate, it is found that a similar phenomenon is also produced when one frequency approximates to a multiple or fraction of the other and some interesting features are to be found by studying the record of Fig. 23, which records the beat phenomena with two waves A and B of different amplitudes.

To obtain this record, on Fig. 23, the frequency of A was kept constant and the frequency of B varied from a top limit where B was more than twice the frequency of A, to a lower limit where B was less than one-third A. From examination of this figure it is seen that beating effects are produced at points where B approximates to twice, equal, half, and one-third, the frequency of A, that is to say at any harmonic, the points of zero beat at each stage being clearly defined. One frequency was not continuously varied at a constant rate, but changed in steps so as to show more clearly the more interesting stages. If observation is made of the record it will be noticed that as one recedes from either side of each "zero beat" point, beats quickening in frequency are observed, and at periods midway between two successive zero beat points the character of the envelope appears indeterminate and presumably at such periods no periodic beat frequency will be in evidence.

A further point observed is that at periods where B approximates to twice and half A, the beat produced is not symmetric, the crest of the envelope on one side coinciding with a hollow on the other. This means that the datum line varies with

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the envelope. On the other hand the beat at periods where B approximates to A and one-third A, the beat is quite symmetric, and thus the analysis suggests the rule that beats obtained with odd multiples in practice will be symmetric, and those obtained with even multiples will be assymmetric.

As in the case previously considered, the actual character of the wave is dependent upon the relative amplitude of the beating waves, A and B, although the general form of beat will persist.

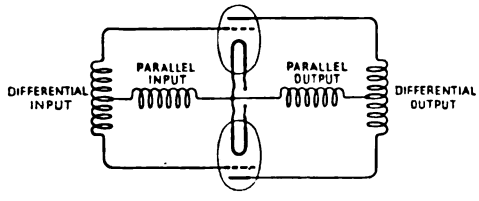

FIG. 24.

Consider the case of one frequency nearly twice the other. If the amplitude of the lower frequency is stronger than that of the higher, only a single note and a single beat is in evidence, throbbing at the low tone.

On the other hand, if the higher frequency has the stronger amplitude, frequency doubling occurs and two sets of beats will be observed. That is, a beat throb will be observed at the higher tone and a second beat throb of the same frequency mingling with it, at the lower tone.

To obtain the value of the beat the following rule can be applied. One wave will be either a multiple (or fraction) or approximate to a multiple (or fraction) of the other. Assume one frequency to be a fraction of the other frequency. Multiply the fraction by its denominator, take the difference of the figure obtained and the other frequency, and this difference will give the beat in terms of the fractional number and can then be reduced.

For instance a signal of frequency 1,000,000 beating with a local oscillator of 500,010. The latter is nearly one half.

Signal		1,000,000
Heterodyne 500,010 (multiply by 2)	=	1,000,020
		20

Thus the beat is 20 in 500,010 and reducing this one gets a beat every 500,010/20 waves or one beat in 25,005 cycles.

Section 4—A Mechanical Investigation of " Push-Pull " Circuits.

The name " push-pull " in wireless work is given to those circuits impulsed by two valves acting differentially. Of course it is not necessary to employ two valves to obtain a push-pull action, nor does the name adequately describe the circuit to

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which it is applied, for with this system it is possible to obtain a variety of effects, some of which are quite the reverse of push-pull.

Fig. 24 shows a general form of push-pull circuit from which it can be seen that input can be applied either at parallel or differential input, and output can be obtained from either parallel or differential output. Further, either valve may be set to the middle of its characteristic, or set to bottom or top rectifying point. Thus it can be seen that a variety of results may be possible with different settings, and it is a convenience to be able to study such a circuit mechanically.

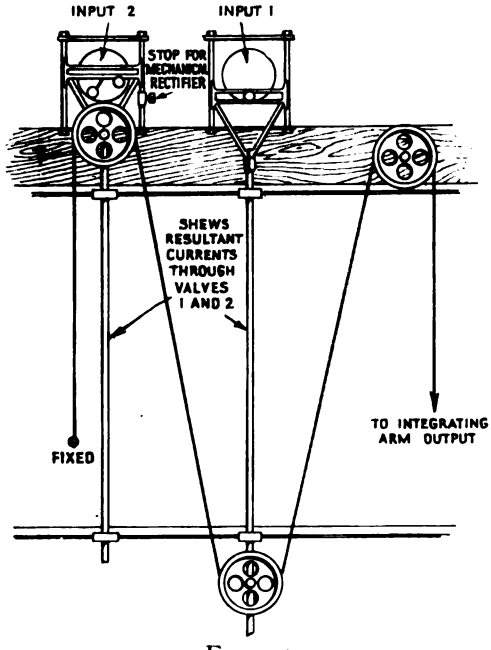

FIG. 25.

Before showing some of the results obtained, a brief indication will be given as to how the model can be set up to demonstrate the push-pull circuit.

The input sinusoidal voltages are obtained of course from the rotating cranks, say input to 1 being obtained from crank 1 and put to 2 from crank 2.

The valves are the crossheads, and should it be desired to set the valves at their rectifying point, this can be done by allowing the crosshead to operate only to such portion of the cycle as would be determined by the setting of the valve. For instance, suppose the valve is to be set to its bottom rectifying point. To do this the crank pin is lifted out of the slide block, and fixed below the crosshead so that the latter can only be impulsed upwards. The crosshead can then be prevented from moving below any predetermined point by a stop, and thus, for complete bottom bend rectification this stop would be set so as to prevent the crosshead moving below zero amplitude. If now any sinusoidal wave be applied to the input crank this wave is automatically rectified by the crosshead, this mechanical rectifier being, of course, a " perfect " device and not having a " square law " as is usually the case.

Thus the trace from a crosshead records plate current through that valve, and not input, and the output current from the two mechanical valves can be combined

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differentially as for an output 3, or in parallel as for an output 4. To arrange the valves to combine differentially, that is for a push-pull output, the integrating string must be changed from its usual order and fixed as shown in Fig. 25, so that movements in opposition add to one another, whereas for a common output 4, the usual arrangement of string is retained.

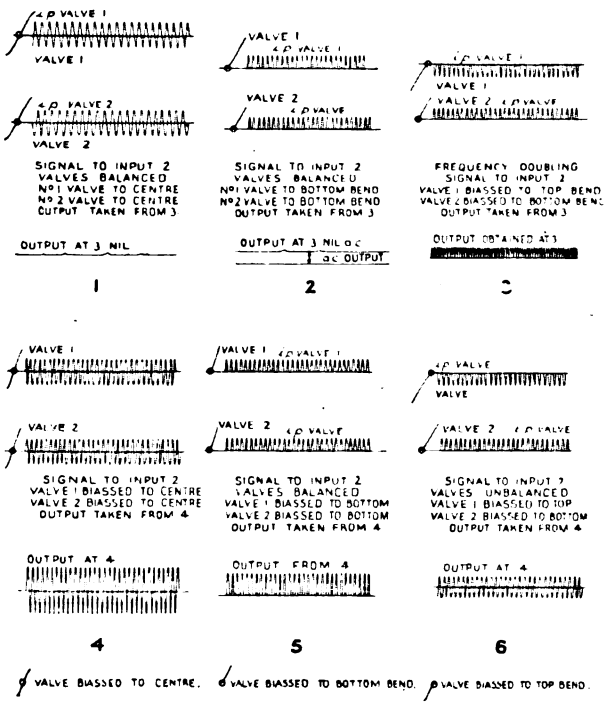

FIG. 26.

The various combinations of results obtained from such a circuit are interesting, and a few of them will be found in Fig. 26.

Section 5—The Synthesis of Alternate Current Waveforms.

It is well known that any periodic waveform can be analysed into a series of sinusoidal components, and although the machine is not reversible and capable of analysing, the investigation of a known series can be carried out and useful information obtained.

For instance, a square signal wave is represented by the expression

$$Ft = A \sin ft + \frac{A}{3} \sin 3\,ft + \frac{A}{5} \sin 5\,ft + \frac{A}{7} \sin 7\,ft \text{ etc. } . . . . . \text{ to infinity}$$

Hence perfect reproduction of a morse signal should involve theoretically the transmission of this infinite series.

Obviously it is neither economic nor necessary to reproduce the complete set of harmonics, but it may be of interest to see how little one can transmit and still obtain a signal of sufficiently good formation for practical purposes.

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Fig. 27A shows a signal with the third and fifth harmonic and Fig. 27B up to the eleventh harmonic, from which one can observe that after the fifth very little is gained in signal formation.

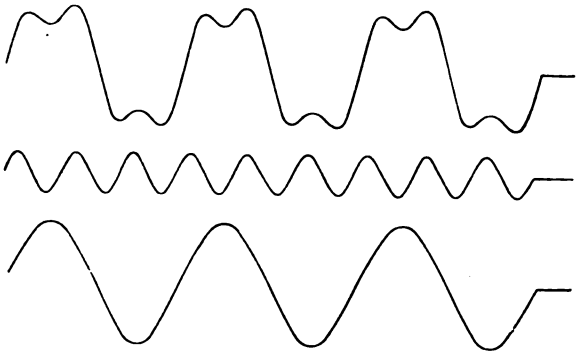

FIG. 27A.

A further point which is sometimes of interest, is the effect on the waveform, of phase shift of the different component frequencies and investigation of this point

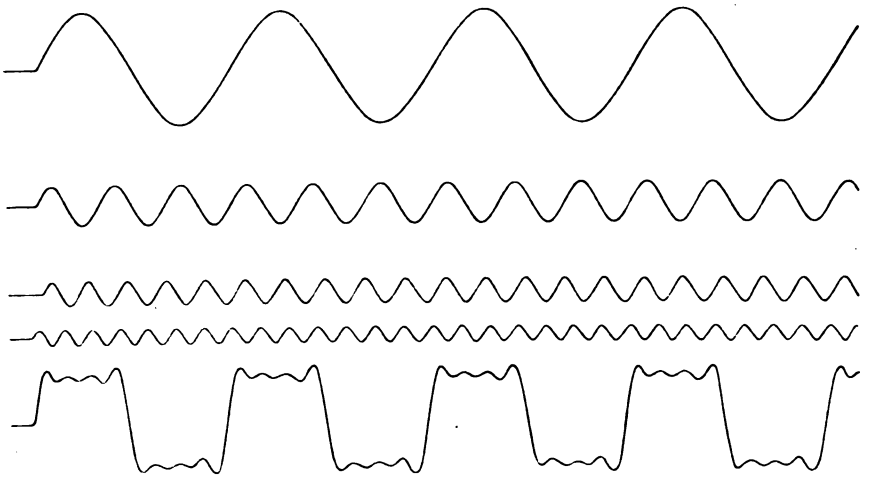

FIG. 27B.

can be carried out very quickly, an example of the use of this being given in the previous section of this paper dealing with single side band working.

A. W. LADNER.

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AN AIRCRAFT DIRECTION FINDER
TYPE A.D.16

The A.D.16 aircraft direction finder, to be described in the following article embodies all the latest refinements in direction finding equipment, and combines great sensitivity with extreme lightness, simplicity of control, and interference due to the ignition and electrical systems of the aeroplane, is reduced to a minimum by suitable screening.

The weight and size of the instrument has been reduced to the minimum possible by the use of light-weight woods, metals, and the compact construction of the components.

The A.D.16 receiver operates on the Marconi Bellini-Tosi system and utilises a system of fixed frames in conjunction with a radiogoniometer.

The amplifier of the A.D.16 direction finder has been made extremely selective and sensitive in order to ensure the greatest possible range even when employing the very small frame aerials, the use of which is rendered necessary by the all-metal construction of modern aircraft.

THE type A.D.16 aircraft direction finder can be described conveniently under the following headings :—

(1) The aerial system.
(2) The radiogoniometer and tuning circuits.
(3) The amplifier.

1. The Aerial System.

A photograph of the latest type of screened aerial for use with the A.D.16 is shown below. It will be seen to consist of two rectangular loops, each consisting of several turns of insulated wire, completely screened by stream-lined duralumin tubes.

This type of aerial is similar in construction and principle to the F.g.6 type of aerial, a photograph of which was given in the MARCONI REVIEW, No. 8, page 6. The weight and air resistance of the frame has been reduced to the minimum consistent with necessary conditions, such as the pick-up area and maximum clearance from the metal structure of the aeroplane.

2. Radiogoniometer and Tuning Circuits.

The aerials are connected to the radiogoniometer in the usual way, calibrating chokes being placed in one or other of the aerial leads in order to make the receiving power of each equal. The chokes consist of two air core inductances of 50 turns provided with a number of tappings.

The radiogoniometer consists of two field windings at right angles to each other and a rotatable search coil movable by an external handle to which is attached a pointer moving over a graduated scale. The pointer is fitted with a "swing

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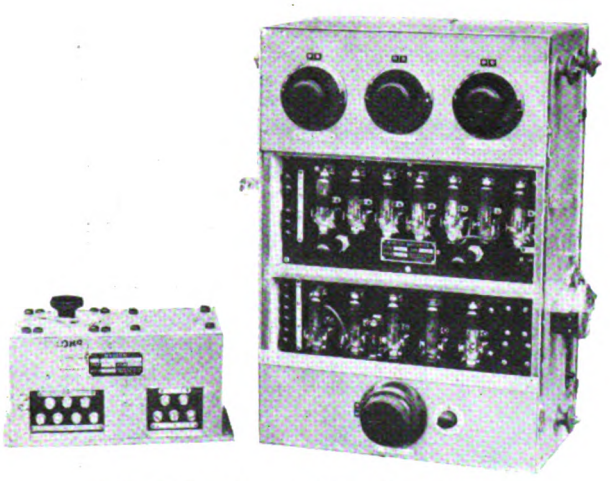
bisector " which enables the operator to take readings on the direction finder and to observe the compass course at the same time. The scale of the radiogoniometer is engraved every five degrees for the sake of clearness.

The two ends of the search coil are connected to the search coil tuning circuit of the amplifier, consisting of a search coil tuning condenser and coupling coil in series. This coil couples into a closed circuit which is connected to a twelve valve amplifier.



A.D.16 Receiver and Radiogoniometer.

3. The Amplifier.

The amplifier consists of six high frequency magnifiers, a detector, oscillator, two supersonic frequency magnifiers, a second detector, and one note magnifier.

The amplifier and tuning circuits are contained in a box divided into four compartments, the uppermost of which contains the search coil condenser, the coupling coil, and the closed input circuit of the amplifier.

The next panel carries the high frequency portion of the amplifier consisting of the six high frequency transformer coupled valves, and the first detector. The potential of the grids of all the H.F. magnifiers, with the exception of the first, can be suitably varied by means of a potentiometer.

The third panel contains the oscillator valve, the two stages of supersonic amplification, the second detector, and the note magnifier.

The bottom panel contains the oscillator condenser and filament resistance for the valves on the panel immediately above.

On the right hand side of the instrument box is the plug for H.T. and L.T. connection, an on-off switch, and a telephone socket.

The circuit diagram of the complete receiver is shown below. Fig. 1.

It will be seen from this that the input circuit is connected to the grid of the first H.F. valve. The six H.F. valves are coupled in cascade in the usual way and pass the received signal to the first rectifier. The grid of this valve is also coupled

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to the local oscillator which produces the supersonic note which is further amplified in the two stages of supersonic amplifiers. After this process the signals are again rectified by means of a second detector valve, and passed through the note magnifier to the telephones.

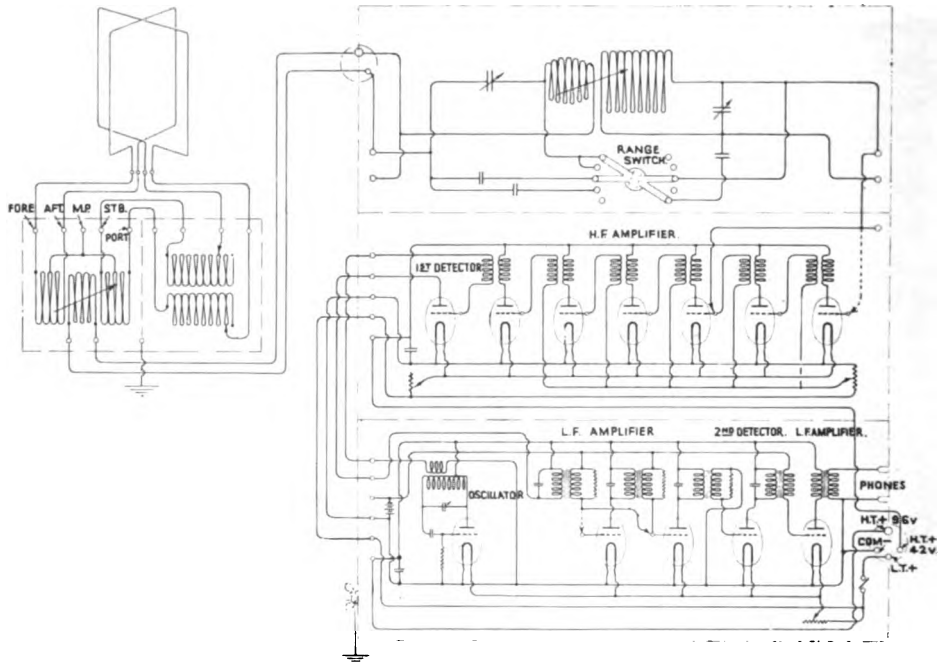

FIG. 1.

The primaries of the supersonic transformers are tuned to the heterodyne by means of a fixed mica condenser, and damping leaks are connected across the secondary windings.

Batteries and Valves.

Low tension current for heating the valve filaments is supplied from a 6 volt accumulator, and the high tension supply is taken from a 96 volt dry battery provided with tappings.

D.E.V. valves are used throughout with the exception of the two rectifiers which use D.E.Q. valves.

Operation.

The A.D.16 direction finder, as has been stated above, employs the Marconi-Bellini-Tosi method of directional reception, and this is so well known as to require no detailed description.

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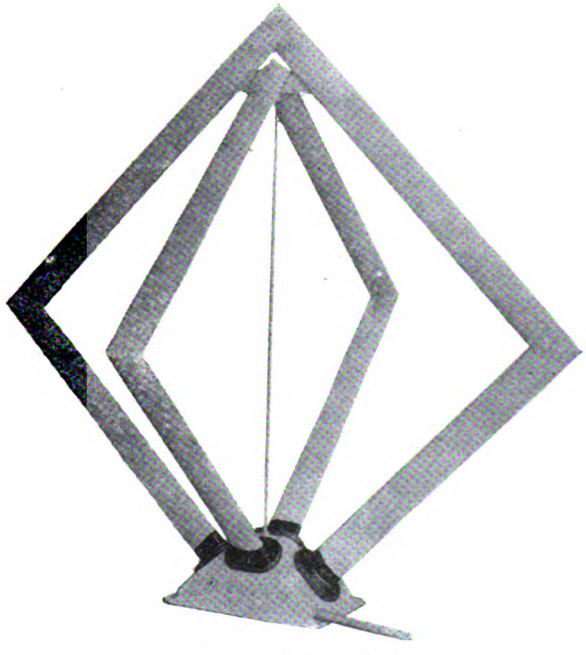
It will suffice to say that the point of minimum intensity of signals on the radiogoniometer is used to determine the direction of the transmitting station.

If it were possible to work under ideal conditions, an absolute extinction of signals could be obtained and bearings could be determined by actually noting the position of this zero. In practice, however, what is known as the " swing " method of taking bearings is generally used. Two points on either side of the minimum are selected such that the signals at these two points appear to be of equal strength. The mean of the readings of the pointer in these two positions will then give an accurate position of minimum signal strength and a correct direction for the received signal.



A.D.16 Frame Aerial.

It will be noted that in the A.D.16 no provision is made for a " sense " determination, *i.e.*, an ambiguity of 180° will always exist as to the direction of any signals, but this can nearly always be eliminated by the knowledge of the operator as to the direction of the aeroplane's flight, etc.

Installation, etc.

It is extremely necessary to screen the ignition system of the aeroplane if the efficiency of the receiver is not to be impaired, due to extraneous interference.

The main portions of an aeroplane ignition system consists of the sparking plugs, the ignition leads to the plugs, and the magneto. Each of these should be carefully screened, the essential factor to be borne in mind being that the electrical resistance of the screening system from plug to magneto should be as low as possible.

In aircraft of " all metal " construction it may be found that elaborate screening is not required, the metal construction acting to a large extent as a natural screen.

The amplifier requires careful suspension and is provided with special lugs and elastic supports.

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COMMERCIAL SHORT WAVE WIRELESS COMMUNICATIONS

PART 1.—THE EMPIRADIO BEAM SERVICES

By H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.

The following is a reprint of a lecture delivered before the Radio Society of Great Britain at the Institution of Electrical Engineers on September 27th, 1929.

The subject of international short wave communication possesses, at the present time, considerable interest, in view of the formation of the new organisation known as "Imperial and International Communications Ltd." which at the end of last month took over the control of the Empiradio, Via Marconi, and Eastern Telegraph Cable services.

The author, in the present article, first describes the working of the Empiradio Beam circuits—the precursor of all other short wave long distance commercial communications—and then proceeds to discuss the world network of short wave radio links of which the "Via Marconi" services form the British section.

THE subject of this lecture as chosen by your Committee may be considered appropriate at the present time, as the Empiradio Beam services of the British Post Office and the "Via Marconi" telegraph services come under the common control this month of the new telegraph organisation known as Imperial and International Communications Limited. Apart from this, the subject undoubtedly has special interest from the amateurs' point of view. The Washington Convention of 1927 drew up a chart of wavelength allocations which on short waves, that is, below 100 metres, provided for amateur working at various bands of wavelengths from 85 m. down to 5 m., and these bands are well distributed between those bands allocated for the use of fixed services.

The phenomena which are met with in commercial short wave working are therefore well known to members of the R.S.G.B., and on the basis of this common experience it may well be that the account I shall endeavour to give (1) of the manner in which the commercial services have applied the knowledge gained during the last few years to the solution of short wave propagation problems, and (2) of the operating technique which has gradually been built up, so that wireless traffic services are now well established between this country and all parts of the earth, on an economic and competitive basis, may prove of special interest to you.

THE EMPIRADIO BEAM SERVICES.

The Empiradio services provide the most striking example of successful commercial short wave working in the world, and we shall therefore consider them first.

The network involved has its imperial centre at the Central Telegraph Office, London, from which the transmitters at Bodmin are operated that communicate with Canada and South Africa, and also the transmitters at Grimsby that communicate with India and Australia.

The incoming signals from Canada and South Africa are received at Bridgwater, and those from India and Australia are received at Skegness, from which two stations they are put on the land lines to the Central Telegraph Office, London.

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The call signs, transmitting wavelengths, and the dates when the Imperial Beam stations were opened for service after completing their acceptance trials are given in the following table.

EMPIRADIO BEAM SERVICES.

Transmitting Station.	Call Sign.	Wavelengths in Metres.	Receiving Station.	Date Service Opened.
Bodmin (England)	GBK	16·574 32·397	Yamachiche ... (Canada)	25th Oct., 1926.
Bodmin (England)	GBJ	16·146 34·013	Milnerton ... (South Africa)	5th July, 1927.
Grimsby (England) ...	GBH	25·906	Rockbank ... (Australia)	8th April, 1927.
Grimsby (England) ...	GBI	16·216 34·168	Dhond ... (India)	6th Sept., 1927.
Drummondville (Canada) ...	CGA	16·501 32·128	Bridgwater ... (England)	25th Oct., 1926.
Drummondville (Canada) ...	CFA	24·793	Rockbank ... (Australia)	16th June, 1928.
Klipheuval (South Africa) ...	VNB	16·007 33·708	Bridgwater ... (England)	5th July, 1927.
Ballan (Australia)	VIZ	25·728	Skegness ... (England)	8th April, 1927.
Ballan (Australia)	VYZ	24·958 16·286	Yamachiche ... (Canada)	16th June, 1928.
Kirkee (India)	VWZ	34·483	Skegness ... (England)	6th Sept., 1927.

Short history of Beam development.

I need only refer briefly to the history of Beam development to remind you of the essential technical features embodied in the equipment of these stations.

The researches of Marchese Marconi and his assistants on short wave directional wireless from 1915 onwards culminated in the proposal put forward by the Marconi Company to the British Government in 1924 for an Imperial wireless network based on the beam system.

This proposal was accepted, and a contract for the erection of the necessary stations in Great Britain was placed with the Marconi Company by the Postmaster-General on the 28th July of that year.

This was followed by contracts in the various Dominions for the erection by the Marconi Company of corresponding stations in these territories. In the case of the British Government stations, acceptance was to be conditional on a continuous seven days test working duplex, at not less than 100 words per minute simultaneously both ways, and exclusive of any repetitions necessary to service accuracy, for 18 hours per day on the Canadian Circuit, 11 hours on the South African, 12 hours on the Indian, and 7 hours on the Australian circuits.

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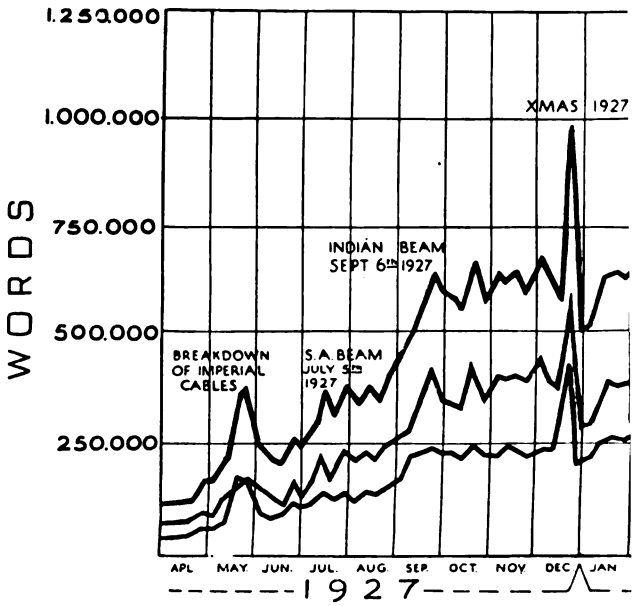
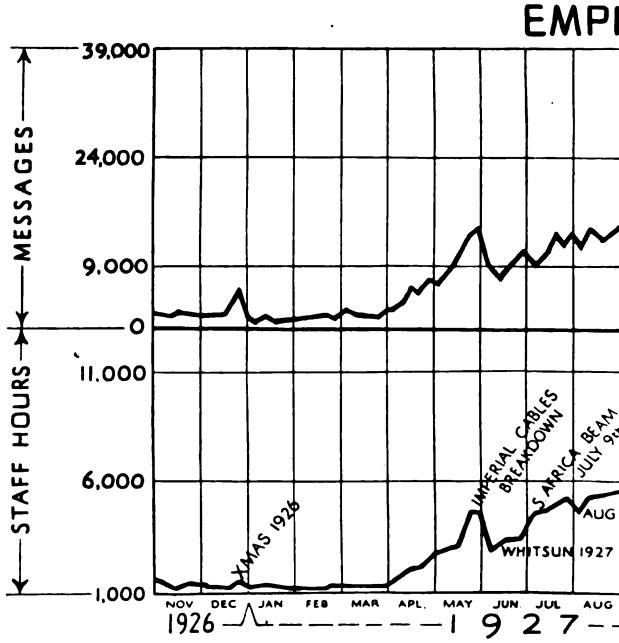
British Post Office Empiradio traffic charts, giving the number of words or messages sent and received per week from the opening of these services to the present date.





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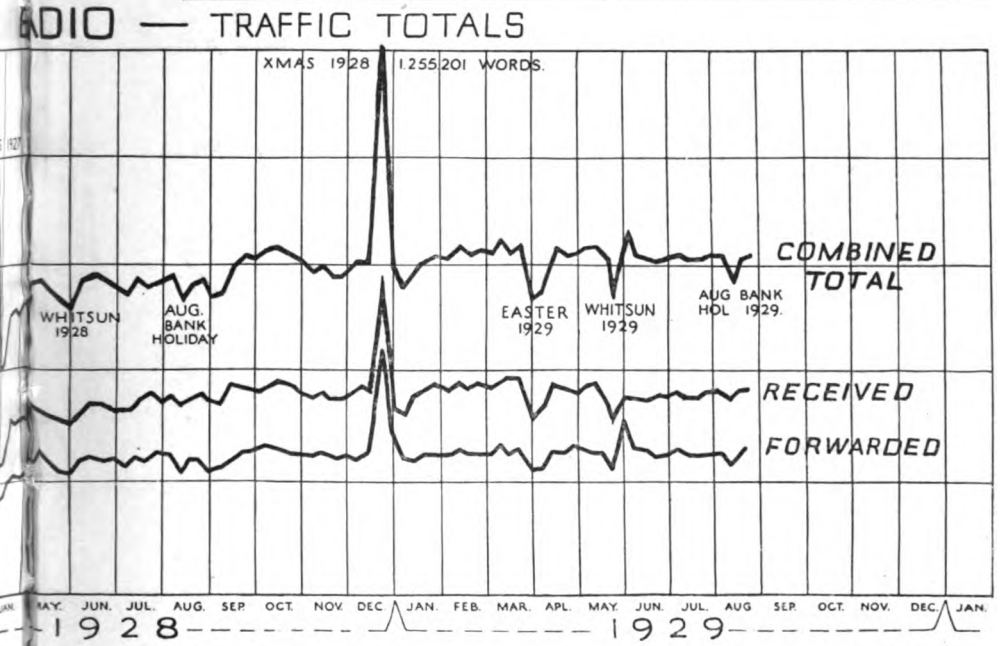
RADIO — TRAFFIC TOTALS
XMAS 1928 1.255.201 WORDS.
COMBINED TOTAL
RECEIVED
FORWARDED
WHITSUN 1928
AUG. BANK HOLIDAY
EASTER 1929
WHITSUN 1929
AUG BANK HOL 1929.
MAY. JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APL. MAY. JUN. JUL. AUG SEP. OCT. NOV. DEC. JAN.
1928 1929

FIG. 1.

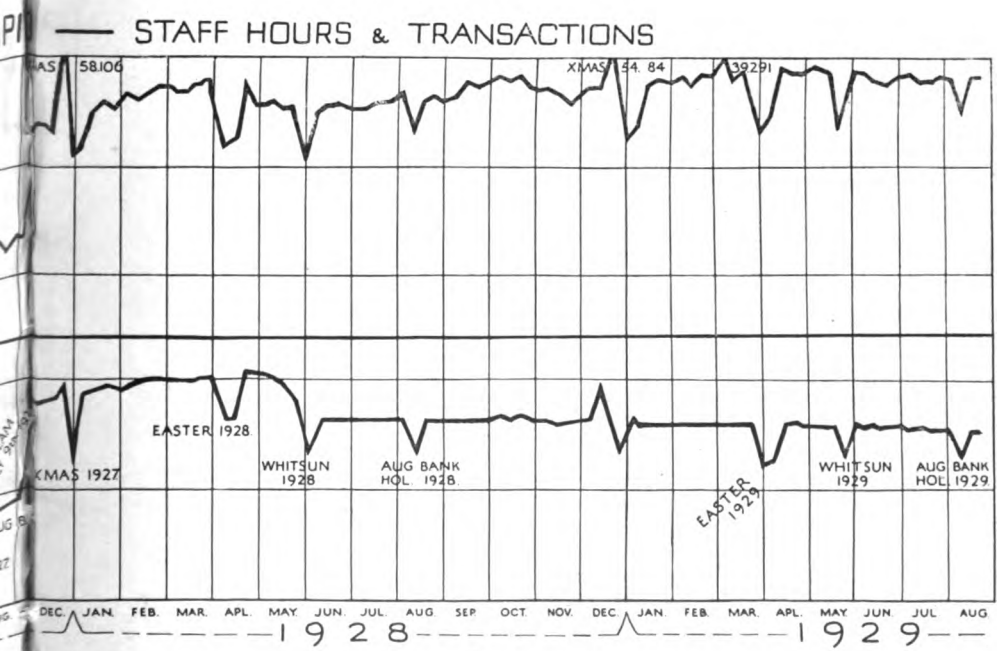

FIG. 2.

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With a certain amount known, and a very great deal unknown of the behaviour of short waves, and of the beam method of propagation at great distances, the Marconi Company leaving the minimum to chance, erected plant suitable for delivering at the maximum distance, a strong high speed signal to the receiver on two optional wavelengths within the range of adjustment of a transmitter of standard design for all the stations, one wavelength for day working, the other for night working.

The best wavelengths for each service were finally settled by test, employing the complete equipment when the stations were actually put into commission. The transmitting reflector concentrates the beam of radiation within an angle of 11°. The transmitter itself is an elaborate design which gives great stability of wavelength, and with 20 kw. to the anode of the first magnifier, provides more than enough power for high speed working. The receiver is designed for strong signals, and the signals are not mutilated by short fade periods.

The generous design of these stations involved the Marconi Company in considerable financial loss, but the desired result was achieved, communications were established which more than fulfilled the guarantees.

Efficiency of Beam plant.

It is now three years since the first Imperial Beam service was opened to the public, and in this period several types of projector aerial have been evolved and employed for commercial working in different parts of the world, but nowhere will you find a concentration of beam radiation in both the horizontal and vertical planes equal to that provided at an Empiradio station ; also, although the number of short wave transmitters which can now be heard on the ether is very considerable, and many of them are crystal controlled, a careful watch will disclose that the Empiradio transmitter has a constancy of wavelength equal to the best of them, and that it is handling more traffic and continuing in service without " sticks " for more hours than any other type of transmitter.

As I shall show you later, rush periods on commercial circuits are generally provided for by bringing additional transmitters into operation, which work on additional channels. But the beam services have passed through several very heavy rush periods and have met all traffic demands without any alteration or addition to the original plant or increase in the number of wavelength channels used, and their capacity for traffic is still much above their present working load.

These are some of the facts which help to explain the astonishing commercial success of the Empiradio services.

British Post Office records.

The Post Office staff, which took over the stations, were both keen and capable, but it was the realisation by the business community that high speed, reliable, long distance transmission at a cheap rate had come at last that sent the traffic figures up by leaps and bounds. The Post Office organisation made a full response to the requirements of the service, and by the kind permission of the Controller of the Post Office, I am able to illustrate this point graphically in Figs. 1 and 2, which incidentally give the full traffic history of the Imperial Beams to date.

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In a communications service the traffic must be sent when it is offered, the load may fluctuate rapidly, and the apparatus must be capable of handling at any time a great increase on its normal load without any sacrifice of readability, or else fail to satisfy the public.

At rush periods, the operating staff at the Central Office may require to be temporarily augmented, to be reduced again, and the men re-absorbed into other work as soon as normal conditions again prevail.

These conditions on a scale which was quite unexpected were satisfactorily met by the Post Office staff. With the Canadian and Australian beams both working the first severe test came when the Imperial Cables broke down in June, 1927. The incoming and outgoing traffic immediately doubled, rising to 50,000 words per day. When the South African service commenced working in June this figure was maintained and was increased in September, 1927, by the opening of the Indian service to an average for the four duplex circuits of 90,000 words per day.

The Christmas traffic averaged in 1927 140,000 words per day, and in 1928, 180,000 words per day. There is a seasonal dip during the summer, but the traffic on the Imperial beam services is still steadily increasing.

The significance of the staff hours curve is as follows: The amount of traffic attracted by the Beam services when they were opened to the public was much greater than had been expected or provided for. Men had to be employed whose experience was limited, and who had to make up in numbers what they lacked in expert speed. As the staff became more expert; the numbers were reduced, and it will be seen that at the present time, a gradually increasing traffic is carried with a staff which still shows a slight tendency to decrease.

Beam Station equipment.

The distinctive features of the Empiradio Beam equipment are :—

(1) The Aerial and Reflector.
(2) The Aerial Feeder system.
(3) The Transmitter.
(4) The Receiver.

A brief description of these essential parts is as follows :—

(1) The Marconi-Franklin Aerial systems at the Bodmin transmitting station are shown in Fig. 3.

There are two sets of five masts, one set supporting the two aerials of the Canadian circuit, and the other set supporting the two aerials of the South African circuit. The layout of each row of five masts is arranged so that the great circle bearing on the distant station with which that particular Beam aerial is designed to communicate, is at right angles to the line of the masts.

The masts are 287 ft. high with 90 ft. cross arms, and are spaced 650 ft. apart.

Each aerial occupies two bays between the masts, and consists of a parallel sheet of elements made up of a number of vertical doublets linked by phasing coils.

The aerial wires are spaced about one quarter wavelength from a screen of twice as many reflector wires.

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The aerial arrangement is such that the currents fed into the parallel wires of the aerial are all in phase. Under this condition the energy radiated from the individual wires cancels out in the plane of the wires but adds in the direction at right angles to this plane.

The effect of the reflector is to cut off the back radiation from the aerial and strengthen it in front, and the total result is a strong beam of radiation confined almost entirely to one direction only and spread over an angle determined by the dimensions of the aerial.

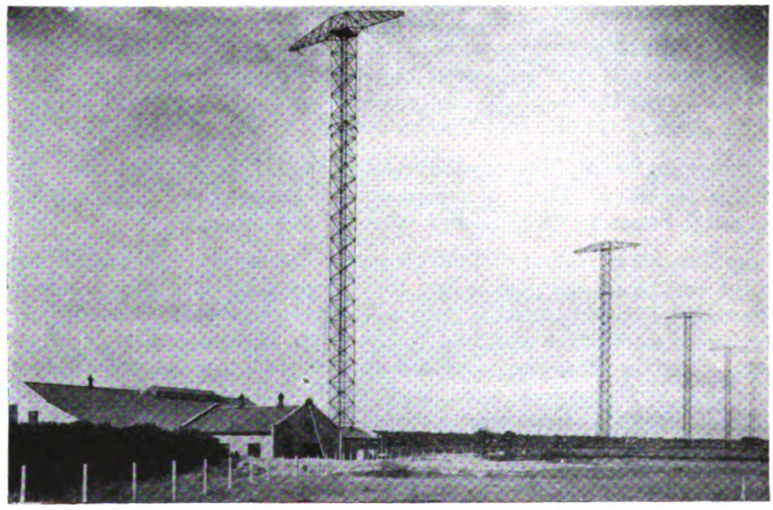

FIG. 3.

The aerial systems of the transmitting and receiving stations are identical.

The masts and aerial systems at Grimsby and Skegness employ a single reflector with an aerial on each side of it, so that by changing over from one aerial to the other the direction of the beam projected round the earth can be altered.

(2) Current is fed into the aerial from the transmitter or conveyed from the aerial to the receiver by means of a special feeder system of concentric copper tubes, the outer one of which is earthed, and so arranged that the length of feeder to each individual aerial element is electrically the same, which ensures that the currents in all the aerial wires are in phase.

(3) Fig. 4 shows the interior of Bodmin station, with the four panel Canadian transmitter on the left, and the South African transmitter which is similar on the right. The station precision wavemeters are on a bench in the centre. The rectifiers and the smoothing circuits for the H.T. D.C. supply to the valves are in another part of the building.

The Marconi Beam Transmitter.

The circuits of the transmitter are shown in Fig. 5.

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Stability of wavelength is obtained in the first place by a control circuit, and in the second place by the extreme care taken in the construction of the set. The drive, or master oscillator which maintains the intermediate and main oscillatory circuits on its own frequency, is carefully screened from the other circuits except at the point where it is weakly coupled to the next stage known as No. 3 Magnifier. This is in part an amplifying circuit, and in part a stabilising circuit which by acting as a buffer between the drive and power circuits proper, helps to maintain the constancy of the drive wavelength when keying.

FIG. 4.

As in the case of the drive, the No. 3 Magnifier is carefully screened except at the point where it couples to the next stage known as No. 2 Magnifier, which in turn is coupled to the grid circuits of No. 1 Magnifier, the main power oscillator of the transmitter in which oil-cooled valves are employed.

The four panels of the transmitter comprise :—

No. 1 Panel.—The No. 1 Magnifier.

No. 2 Panel.—No. 2 and No. 3 Magnifiers and the Drive for the first optional wavelength.

No. 3 Panel.—No. 2 and No. 3 Magnifiers and the Drive for the second optional wavelength.

No. 4 Panel.—The main and sub-absorbing and keying circuits, which, by means of two oil-cooled valves in parallel, divert the H.T. supply through resistances during the spacing periods, and so keep a constant load on the generators.

When changing over from the day to the night wave therefore, Panel No. 1 is readjusted, Panel No. 2 is cut out, Panel No. 3 is switched in, and Panel No. 4 continues as before.

Time will not allow me to describe the transmitter circuit in more detail.

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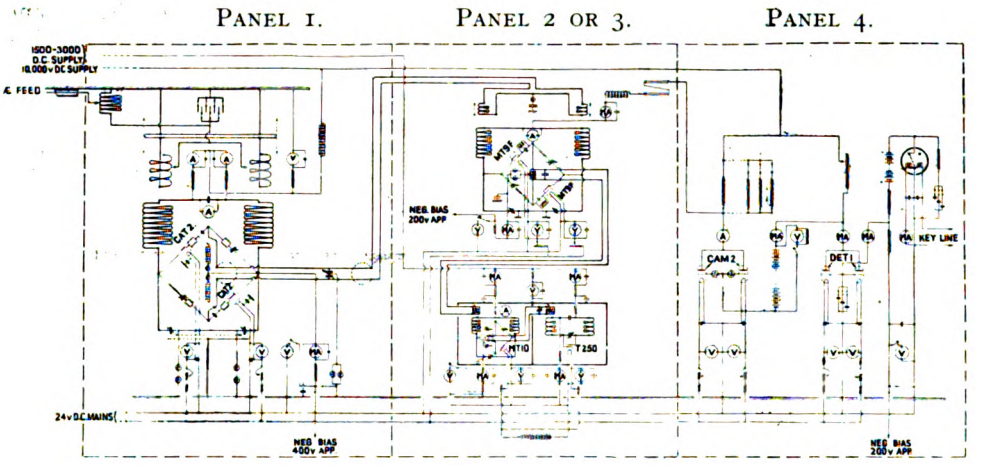

FIG. 5.

The Marconi Beam Receiver.

The receiver consists of a number of carefully screened stages mounted in a rack as shown in Fig. 6.

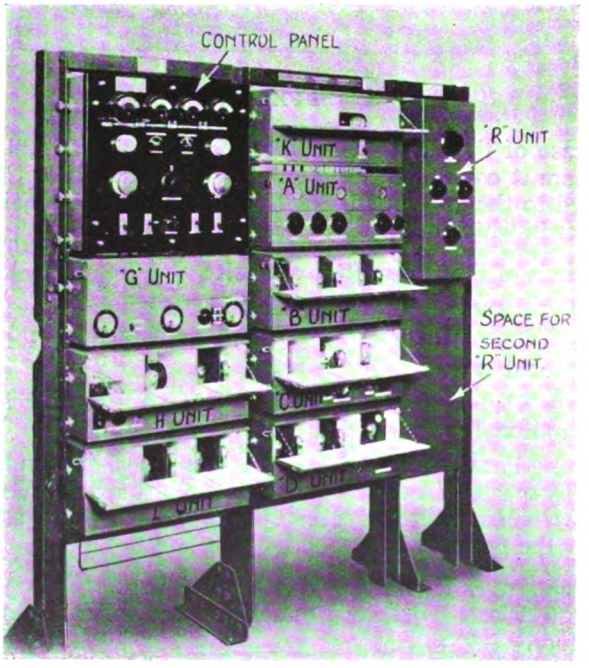

FIG. 6.

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In addition to the switchboard, there are nine boxed units, the function of which, following the lettering on the photograph is as follows :—

R. Feeder Terminal Unit.
A. Intermediate Tuning Unit and First Heterodyne.
B. H.F. Amplifier and Filter Unit.
C. First Rectifier.
D. L.F. Amplifier and Filter Unit.
I. L.F. Amplifier and Filter Unit.
H. Second Rectifier.
G. Limiting Unit.
K. Modulating Unit.

The whole chain of operations from feeder to recorder is shown perhaps in a better general way in Fig. 7.

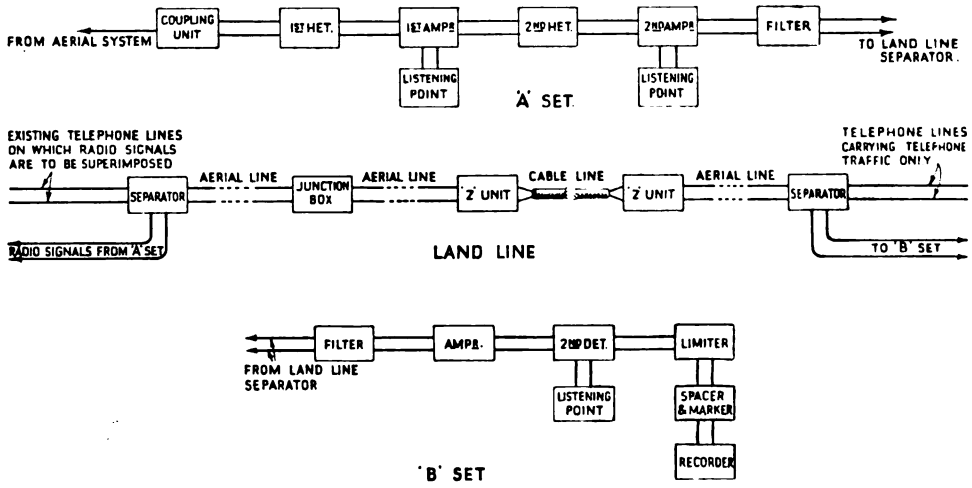

FIG. 7.

This indicates the progress of the signal through the various stages of the " A " set apparatus at the receiving station, whence it is put on to the air-line, then possibly through buried cable to the " B " set apparatus at the Central Telegraph Office where it makes its final appearance on the recorder tape.

(The actual circuits are shown in THE MARCONI REVIEW, No. 4, on page 26.)

The feeder connection is made at the " R " unit which according to the wave-length received may either be a simple tuning circuit, or a tuned valve circuit to magnify the input signals.

The " A " unit includes an intermediate tuning circuit and first stage heterodyne which produces a beat wave of about 1,600 m.

The signal then enters the " B " unit which includes a 3-stage amplifier and filter which gives uniform amplification over a frequency band of 5,000 cycles.

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The " C " unit contains the first rectifier, the second heterodyne which converts the signals to a wavelength of 10,000 metres.

The " D " unit is a second amplifying filtering unit for the 10,000 m. signal, limiting the band width to 3,000 cycles.

There are two further amplifying and filtering stages in the " I " box, and the " H " box contains the final push-pull rectifiers and second " listening " circuit.

The " G " unit comprises a limiting valve and two valves for operating the recorder.

The " K " unit contains a modulating valve and circuits to allow the H.F. oscillations generated by the first heterodyne to be modulated at 1,200 cycles, so that the operator can listen in at the first stage of the receiver.

Bridgwater Receiving Station.

In the view of the receiver room at the Bridgwater Beam station, Fig. 8.

FIG. 8.

the two receivers for the Canadian and South African services occupy the middle of the picture, and in front of them are the undulators of the monitoring circuits with line apparatus to enable the operators on watch to communicate with the Central Telegraph Office or the Transmitting Station at will.

The Multiplex apparatus is in the rack on the left. This is not yet part of the standard equipment, but is at present receiving all the beam telegraph traffic from Canada in place of the usual receiver, and its second channel is employed for beam telephony tests as and when required.

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The third channel is used for telegraph traffic when necessary.

Propagation Characteristics.

It may be as well now to discuss briefly the conditions of propagation which exist in the communicating medium between the wireless transmitting and receiving stations, and which periodically alter according to whether the great circle path through the two stations is in daylight, twilight, or darkness, or is in a combination of all three states.

A careful systematic study extending over a considerable period has been carried out by the Marconi Research Department at Chelmsford on the strength of signals received from a large number of stations at various distances and on various wavelengths, during the day and during the night, and on the basis of these observations, the signal strength attenuation curves shown in Fig. 9 for all daylight propagation have been prepared.

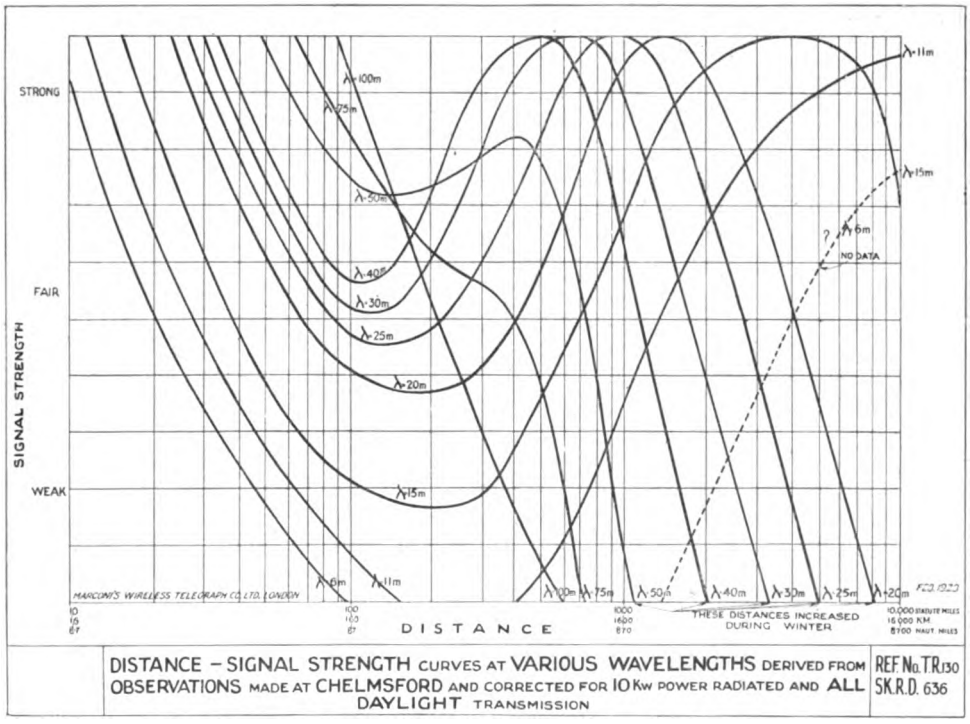

FIG. 9.

It will be seen that on all wavelengths within the range 15 to 100 m., the signals fall off in strength up to 100 miles, but below 60 m. there is a recovery of signal strength with increase of distance, the extent of the recovery being greater the shorter the wavelength used, 15 metres for instance producing a strong signal at 9,000 or even 10,000 miles during daylight.

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The accepted explanation of these effects is that at distances within a 100 miles or so of the transmitter, propagation depends mainly on the direct rays which leave the aerial at low angles, the energy from which is soon absorbed, whereas at great distances, the received energy is obtained from the radiation leaving the transmitting aerial at higher angles which enters the Heaviside layer and travels along it with minimum absorption and is finally bent down earthwards again, the actual angle incident to the ground at which the rays reach the receiving aerial being about 15°.

The signal strength attenuation curves compiled from the records for all night propagation conditions are shown in Fig. 10.

It will be seen that 15 m. is a bad night wave for long distance, and that in general there is improved working up to 30 m. with some falling off in range again above that value.

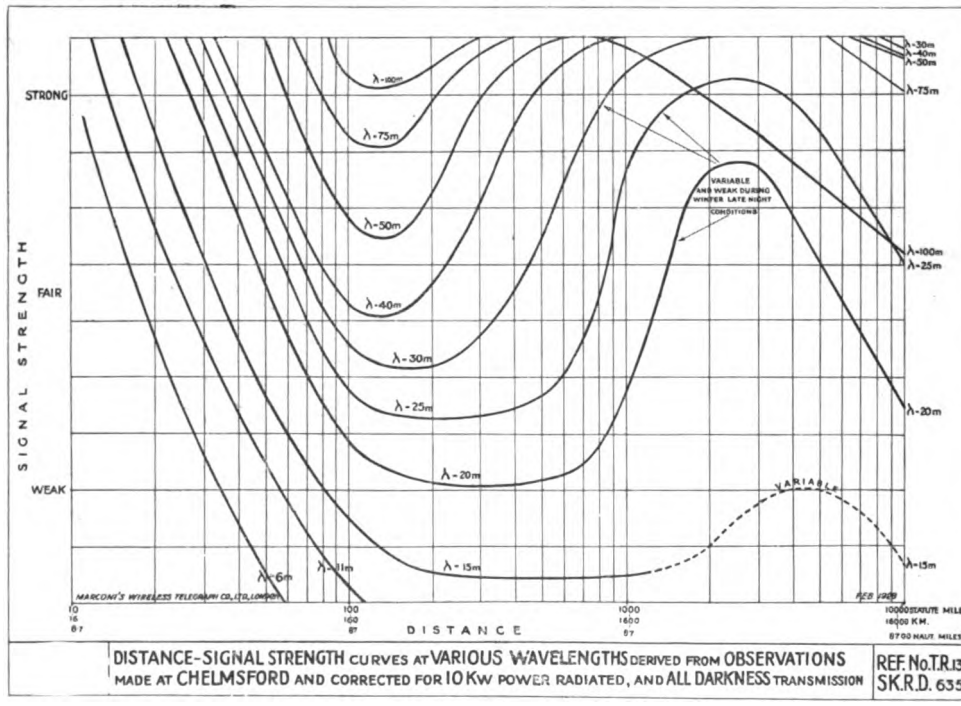

FIG. 10.

Now these two sets of curves are just average propagation characteristics for daylight and darkness. There are, in addition, seasonal changes to be allowed for, and different parts of the earth at the same distance from the transmitter show local differences in signal strengths received, which can only be definitely determined by actual tests between the stations concerned. How these effects are likely to influence communications is indicated in the following charts.

Beam Station reception characteristics.

The first one, Fig. 11, shows the mean signal intensities for 24 hours for the 34 metre wavelength used on the Cape Town—Bodmin circuit as measured at

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Chelmsford. The three curves give the different values for summer, the equinoctial periods, and winter.

It will be seen that this wavelength is no good for transmission from 8 a.m. G.M.T. to 8 p.m. G.M.T.

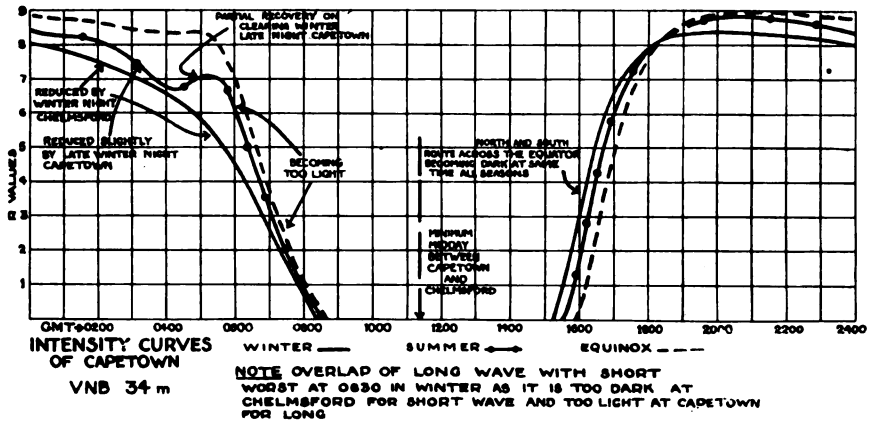
PARTIAL RECOVERY ON CLEARING IN WINTER LATE NIGHT CAPETOWN
REDUCED BY WINTER NIGHT CHELMSFORD
REDUCED SLIGHTLY BY LATE WINTER NIGHT CAPETOWN
BECOMING TOO LIGHT
NORTH AND SOUTH ROUTE ACROSS THE EQUATOR BECOMING DARK AT SAME TIME ALL SEASONS
MINIMUM FRIDAY BETWEEN CAPETOWN AND CHELMSFORD
R VALUES
GMT→0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400
INTENSITY CURVES OF CAPETOWN
VNB 34 m
WINTER
SUMMER
EQUINOX
NOTE OVERLAP OF LONG WAVE WITH SHORT WORST AT 0630 IN WINTER AS IT IS TOO DARK AT CHELMSFORD FOR SHORT WAVE AND TOO LIGHT AT CAPETOWN FOR LONG

FIG. 11

A day wave of 16 m. is therefore used which allows traffic to be sent during the whole of what would otherwise be a blank period, and by this arrangement, the circuit is able to provide a 24 hours service.

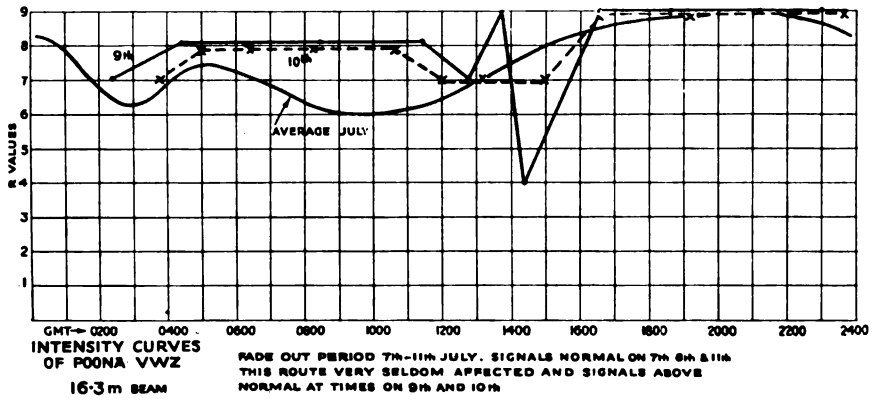
9th
10th
AVERAGE JULY
R VALUES
GMT→ 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400
INTENSITY CURVES OF POONA VWZ
16·3 m BEAM
FADE OUT PERIOD 7th–11th JULY. SIGNALS NORMAL ON 7th 8th & 11th
THIS ROUTE VERY SELDOM AFFECTED AND SIGNALS ABOVE NORMAL AT TIMES ON 9th AND 10th

FIG. 12.

I can show you a 16 m. record taken on another circuit, the incoming beam signals from Poona, India, Fig. 12. This chart first of all shows the average signal strengths for the 24 hours during the month of July, and it will be seen that from 8 a.m. to 8 p.m. G.M.T. the signal strength was quite good enough for commercial working. But there are other points of special interest peculiar to the Indian beam service which are brought out by this record.

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You are aware that during periods of great sunspot activity, pronounced fade-out of signals may sometimes be experienced on Short Wave circuits.

The Indian beam service is remarkably free from serious perturbations of this character.

One such fade-out period occurred from the 7th to the 11th July, 1928, yet during that time as stated on the chart, signals were normal on the 7th, 8th and 11th, and on the 9th and 10th the signal strength curves show that communication was at no time interrupted, and the worst period lasted only a couple of hours.

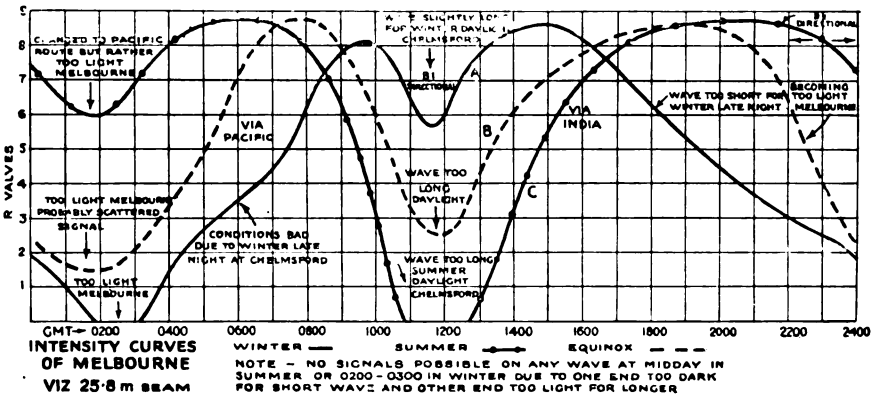
R VALVES
VIA PACIFIC
VIA INDIA
WAVE TOO LONG DAYLIGHT
WAVE TOO LONG SUMMER DAYLIGHT CHELMSFORD
CONDITIONS BAD DUE TO WINTER LATE NIGHT AT CHELMSFORD
TOO LIGHT MELBOURNE PROBABLY SCATTERED SIGNAL
TOO LIGHT MELBOURNE
WAVE TOO SHORT FOR WINTER LATE NIGHT
BECOMING TOO LIGHT MELBOURNE
GMT 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400
INTENSITY CURVES OF MELBOURNE
VIZ 25·8 m BEAM
WINTER
SUMMER
EQUINOX
NOTE - NO SIGNALS POSSIBLE ON ANY WAVE AT MIDDAY IN SUMMER OR 0200 - 0300 IN WINTER DUE TO ONE END TOO DARK FOR SHORT WAVE AND OTHER END TOO LIGHT FOR LONGER

FIG. 13.

Signal strength values measured on the Melbourne beam are shown in Fig. 13. This chart is of particular interest because the circuit is worked for the whole 24 hours on one wavelength. The reason for changing the wavelength as you know, is because the propagation conditions alter. But at the antipodes, the propagation characteristics for the first twelve hours of the 24 can be kept approximately the same for the second twelve hours by reversing the direction of the beam, and this is what is done. Aerials are fitted in front and at the back of the beam reflector. For twelve hours or thereabouts, traffic is sent to this country via the Pacific, and when signals commence to fall off, a change-over of aerials takes place, and traffic then reaches this country with increased strength via India.

Traffic Speed Charts.

All the wireless apparatus in the Beam stations is capable of working at 300 words per minute if necessary.

In practice, the reception conditions are indicated in a general way by the traffic speed charts which are compiled for each service. These charts give the number of words per minute at which traffic is received during the 24 hours, with remarks on operating conditions. The speed and number of working hours are of course affected by the amount of traffic on hand, but on the beam services there is always sufficient traffic offered to keep the circuit busy for 24 hours.

Taking the results obtained on the Indian beam service as typical, Fig. 14 shows the traffic conditions on one day in July this year at Dhond, India, receiving from

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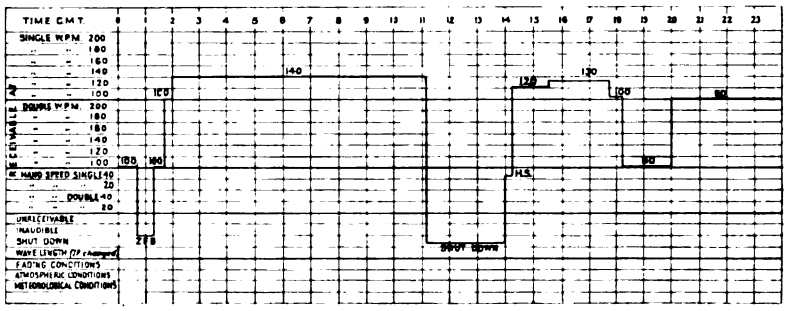
Grimsby. The service was working on 16 m. wavelength for 20 hours out of the 24, during nine hours of which traffic was received at 140 words per minute, and for various periods at lower speeds down to 80 words per minute.

Traffic the other way is indicated in Fig. 15, which shows the traffic conditions at Skegness for a day in July this year, also on one of the 16 metre waves.

LOG OF RECEPTION CONDITIONS AT DHOND, INDIA, FROM GRIMSBY GBI. *7th July*, 1929.



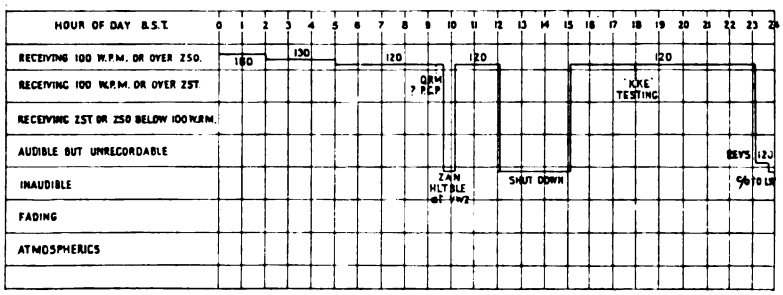
Wavelengths 16·216 m. and 34·168 m.

FIG. 14.

The stations were in communication some 20 hours, the maximum speed was 160 words per minute falling to 120 words per minute. There was a change-over to the 34 m. wave at midnight.

From the speeds of working at the times of shut-down and starting-up again, it is clear that if necessary on these two days, the stations could have been passing traffic for twenty-three out of the twenty-four hours, and such conditions are normal on the Indian beam service.

LOG OF RECEPTION CONDITIONS AT SKEGNESS, ENGLAND, FROM KIRKEE, INDIA VWZ. *14th July*, 1929.



Wavelengths 16·286 m. and 34·483 m.

FIG. 15.

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Transmitting Station Routine.

The routine at the transmitting stations is to start up the plant and keep it going.

Two monitoring undulators, one on the line from the Central Telegraph Office, the other on a pick-up circuit from the transmitter, indicate the quality of signals passed into and out of the transmitter on to the aerials.

When no messages are being sent, a reversal slip is used on the Central Telegraph Office Wheatstone, to keep the line occupied, and the distant station advised that the circuit is still alive and likely to send traffic at any time.

The change of wavelength is usually done after advice has been received from the other end that signals are failing. If this advice is not given, there is usually a programme time when the change-over is effected.

It may take half-an-hour to effect a change of wavelength, and this is carried out when possible at both terminal stations at the same time. If one station changes over while the other is still sending traffic, as sometimes happens, the first station is sending blind with no means of knowing, until the other station starts up again, whether its messages have been properly received, and this is undesirable.

Receiving Station Routine.

The receiving stations at Bridgwater and Skegness are the actual control points of the four Empire Beam services.

A continuous monitoring watch is maintained on both the incoming and outgoing signals, and according to the conditions prevailing, the receiving station advises the Central Telegraph Office when to change the operating speed, the route, or the wavelength.

Communication by one route or on one wavelength is continued until signals one way or the other fail, when the route or wavelength is changed, and in practice, it is difficult to start the traffic service, incoming or outgoing, until fairly good touch each way has been re-established.

In the case of Australia and Canada, as these stations are in wireless communication with each other, by utilising the station with which London is in communication, it is possible to advise the other as to the possibility of reception, etc., or to use any of the three to pass advice to the other, an arrangement which has been used.

In the event of the beam stations having been out of touch with each other during the period proceeding the anticipated time of change of wavelength or route, the change is made at the normal time and communication established on the new route or on the new wavelength.

(*To be continued.*)

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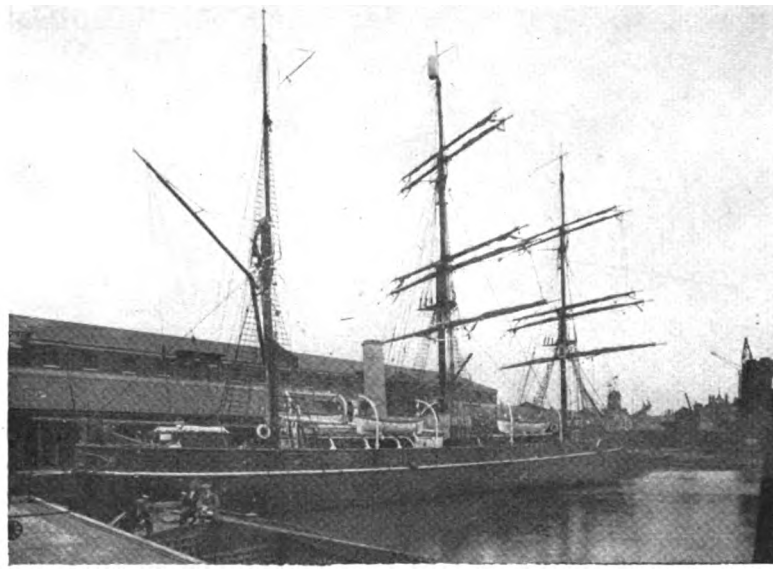
MARCONI NEWS AND NOTES

WIRELESS FOR ANTARCTIC EXPLORATION

THE barque " Discovery," which is now on its way to the Far South for a new voyage of Antarctic exploration, is equipped with Marconi wireless apparatus that will enable it to maintain constant communication.



The " Discovery."

The expedition, which is under the leadership of Sir Douglas Mawson, the famous Australian explorer, has been specially equipped for scientific and survey work in the Antarctic to the South of Australia, and the comprehensive wireless equipment of the " Discovery " will play an important part in keeping the party closely in touch with the scientific world.

For ordinary ship-to-ship and ship-to-shore communication, a Marconi 1½ kilowatt Quenched Spark transmitter and a ship's receiver of the latest pattern are installed. For special messages from the heart of the Antarctic, many hundreds of miles from the nearest point of civilisation, a Marconi short wave telegraph transmitter is to be used for communication with Australia and Great Britain. In conjunction with this transmitter a new Marconi short wave receiver is fitted, so that the explorers will be able to " listen-in " to civilisation.

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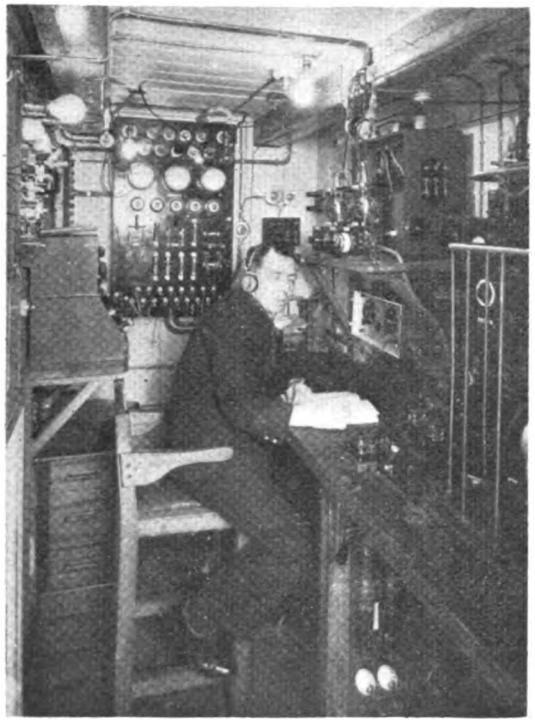
Direction Finder for Navigation.

A Marconi wireless direction finder also forms part of the navigation equipment. The direction finder has already proved of great value in Arctic and Antarctic navigation, and is widely used by whalers and other vessels engaged in the Far Northern and Southern Seas.



Wireless Cabin of "Discovery," showing Marconi Direction Finder, Short Wave Transmitter and Receiver, and Quenched Spark Installation.

The Moth aeroplane to be carried by the expedition is also being equipped with Marconi apparatus. The aeroplane is to be used for scouting purposes within a range of 100 miles of the "Discovery," and it is being fitted with the new Marconi transmitting and receiving set for light aeroplanes, specially adapted for Morse working. During his scouting expeditions the pilot of the aeroplane will thus be able to keep in touch with the base ship, which, by means of its Marconi Direction Finder, will at the same time be able to locate the direction of the aeroplane. In case of a forced landing, an emergency aerial can be rigged on the aeroplane and the generator normally driven by airscrew can be operated by hand. With the power thus supplied, a special automatic code sender will enable messages to be sent from the aeroplane to the ship.

Wireless Men's Accuracy.

A well-deserved tribute to the accuracy and efficiency of wireless operators on Atlantic liners is contained in the annual report of the Director of the Meteorological Office. He says that, although all messages relating to weather are sent in figure code, and frequently during the busiest traffic periods, 4,476 reports, each consisting of eight groups of five figures were transmitted during the year, only two mistakes in every 1,000 figures were made.

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No. 14

THE MARCONI REVIEW

November, 1929

CONTENTS

COMMERCIAL SHORT WAVE WIRELESS COMMUNICATIONS. PART II.—THE "VIA MARCONI" SERVICES - PAGE 1

THE MARCONI TUNING FORK AS A FREQUENCY STANDARD - - - - - - - „ 16

A CONSTANT FREQUENCY CONTROL FOR BROADCAST TRANSMITTERS - - - - - - „ 21

MARCONI NEWS AND NOTES—

BRITISH REGIONAL BROADCASTING - - „ 27

RELIABILITY OF BRITISH BROADCASTING STATIONS - - - - - - - „ 30

NEW SPANISH STATIONS - - - - - „ 31

BEAM TELEPHONY - - - - - - „ 32

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THE MARCONI REVIEW

No. 14. *November, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

COMMERCIAL SHORT WAVE WIRELESS COMMUNICATIONS*

PART II.—THE "VIA MARCONI" SERVICES

The first part of this article appeared in last month's issue and dealt with the Empiradio Beam services.

In the second part, which is given below, the "Via Marconi" services are described.

The concluding section will appear in THE MARCONI REVIEW *for December and will deal with the important foreign services which have their centres at New York, Paris and Berlin.*

THE Empiradio Beam services are exceptional in several respects.

They provide a self contained world system giving an exclusive service between centres serving vast continents that have growing business interests, and which therefore are able to draw on a large and increasing traffic supply.

They work on strong signals with aerial systems and apparatus which are identical at all the terminal points.

A working arrangement with all competing cables has been reached.

In contrast to this approach to the ideal in wireless communications, we shall now consider that extensive and important group of circuits which has its centre at Radio House, London, and is known as the "Via Marconi Telegraph Services."

Spreading over the whole world is a comprehensive network of inter-communicating commercial wireless circuits having its principal centres at London, New York, Paris and Berlin, and the Via Marconi services comprise that large section of this network which is controlled from London.

Many of these communications employ long wave channels, but the majority use short wave, and the number of short wave channels in commercial use is steadily increasing.

What this means can be better understood by reference to the following table.

* The following is a reprint of a lecture delivered by H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E., before the Radio Society of Great Britain, at the Institute of Electrical Engineers, on September 27th, 1929.

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"VIA MARCONI" SERVICES

LONDON—NEW YORK CIRCUIT.

English Transmitters :—		United States Transmitters :—	
GLS	15·00 m. Ongar.	WKM	15·907 m.
GLG	15·74 m. Dorchester.	WTT	15·84 m.
GLH	22·16 m. Dorchester.	WLL	16·760 m.
GLK	37·476 m. Dorchester.	WIK	21·54 m.
		WEQV	21·63 m.
		WAJ	22·24 m.
		WHR	22·35 m.
		2XAM	25·8 m.
		WEL	33·52 m.
		WEC	33·595 m.
		WQO	35·0 m.
		WEM	40·54 m.
		WIZ	43·0 m.
		WEB	43·25 m.
		WQN	59·0 m.
GLC	9,630 m. Ongar.	WSO	11,652 m.
MUU	14,037 m. Carnarvon.	WRT	13,265 m.
		WRQ	13,423 m.
		WGG	13,575 m.
		WII	13,750 m.
		WSS	15,950 m.
		WCI	16,300 m.
		WQK	16,400 m.

LONDON—BUENOS AYRES CIRCUIT.

English Transmitters :—		Argentine Transmitters :—	
GLS	15·0 m. Ongar.	LSE	14·38 m.
GLW	15·707 m. Dorchester.	LSG	15·03 m.
GLY	26·269 m. Dorchester.	LSF	15·35 m.
GLQ	27·45 m. Ongar.	LSH	26·0 m.
		LSI	30·20 m.
		LSD	34·0 m.
		LSC	8,800 m.
		LSA	12,630 m.
		LSB	17,430 m.

LONDON—RIO DE JANEIRO CIRCUIT.

English Transmitters :—		Brazilian Transmitters :—	
GLS	15 m. Ongar.	PPX	14·45 m.
GLW	15·707 m. Dorchester.	PPS	14·5 m.
GLY	26·269 m. Dorchester.	PPU	15·6 m.
		PPW	27·4 m.
		PRLB	37·6 m.
		PRLA	30·0 m.
		PPX2	43·45 m.
		PPR	21,818 m.

LONDON—BELGRADE CIRCUIT.

English Transmitters :—		Serbian Transmitters :—	
GLP	5,332 m. Ongar.	UNB	3,455 m.
		UNA	11,150 m.

LONDON—MOSCOW CIRCUIT.

English Transmitters :—		Russian Transmitters :—	
		RKV	21·0 m.
		RPK	33·8 m.
GLP	5,332 m. Ongar.	RNO	3,475 m.
		RDW	3,500 m.
		RET	3,800 m.
		RAI	7,000 m.
		RAM	10,175 m.

LONDON—PARIS CIRCUIT.

		FRE	15·45 m.
		FSI	25·125 m.
		FTL	30·0 m.
		FS2	40·03 m.
GLB	3,800 m. Ongar.	FTP	2,725 m.
		FTS	3,280 m.
		FTR	9,850 m.
		FTT	14,346 m.

LONDON—BERNE CIRCUIT.

English Transmitters :—		Swiss Transmitters :—	
		HBC	34·5 m.
GLA	2,947 m. Ongar.	HBB	3,135 m.
		HBA	4,230 m.
		HBG	4,400 m.

LONDON—MADRID CIRCUIT.

English Transmitter :—		Spanish Transmitters :—	
		EAN	25·03 m.
		EAQ	30·456 m.
		EAM	30.7 m.
GLO	4,330 m. Ongar.	EAA	3,660 m.

LONDON—BARCELONA CIRCUIT.

English Transmitter :—		Spanish Transmitters :—	
		EAX	31·8 m.
GLO	4,330 m. Ongar.	EAB	3,760 m.

In the above table spaces have been left between long and short wave stations.

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"VIA MARCONI" SERVICES—*continued*

LONDON—VIENNA CIRCUIT.

English Transmitters :—		Austrian Transmitters :—	
GLQ 27·45 m. Ongar.		VOX	23·33 m.
		UOR	29·9 m.
		UOK	40·6 m.
GLP 5,332 m. Ongar.		UOF	2,740 m.
		UOW	3,050 m.
		UOD	3,896 m.

LONDON—LISBON CIRCUIT.

English Transmitters :—		Austrian Transmitters :—	
		CUW	15·66 m.
		CUS	18·17 m.
GLC 9,630 m. Carnarvon.		CUN	1,950 m.
		CUE	6,120 m.

LONDON—STAMBOUL CIRCUIT.

English Transmitters :—		Turkish Transmitters :—	
GLQ 27·45 m. Ongar.			
GLC 9,630 m. Carnarvon.		TAA	10,600 m.
		TAF	1,947 m.

LONDON—BEYROUTH CIRCUIT.

English Transmitters :—		Syrian Transmitters :—	
GLL 21·962 m. Dorchester.		FY	18·6 m.
			22·6 m.
			38·0 m.
GLC 9,630 m. Carnarvon.		FZ	10,220 m.

LONDON—CAIRO CIRCUIT.

English Transmitters :—		Egyptian Transmitters :—	
GLL 21·962 m. Dorchester.		SUZ	21·7 m.
GLQ 27·45 m. Ongar.		SUW	25·17 m.
		SUY	44·248 m.
		SUX	38·5 m.
GLC 9,630 m. Carnarvon.		SUC	11,000 m.

LONDON—BANGKOK CIRCUIT.

English Transmitter :—		Siamese Transmitter :—	
GLQ 27·45 m. Ongar.		HSP	16·911 m.

LONDON—SOFIA CIRCUIT.

English Transmitters :—		Bulgarian Transmitters :—	
		LZA	20·0 m.
		LZB	40·0 m.
GLO 4,330 m. Ongar.		LZS	2,850 m.
GLP 5,332 m. Ongar.			

LONDON—TOKIO CIRCUIT.

English Transmitters :—		Japanese Transmitters :—	
GLX 15·244 m. Dorchester.		JNI	15·79 m.
GLY 26·269 m. Dorchester.		JNR	24·59 m.

Radio House is at present conducting 17 services, namely, to

New York.	Paris.	Lisbon.	Cairo.
Buenos Ayres.	Berne.	Vienna.	Bangkok.
Rio de Janeiro.	Madrid.	Stamboul.	Sofia.
Belgrade.	Barcelona.	Beyrouth.	Tokio.
Moscow.			

The "Via Marconi" services on these 17 circuits transmit on 16 wavelengths, 6 long wave and 10 short wave, and the traffic from the corresponding 17 stations is received on some 94 different wavelengths, 38 long wave and 56 short wave.

To run an undertaking of this magnitude on a successful commercial basis calls for technical and business skill of no mean order, particularly as every one of these routes is already well served by cable or trunk line telegraphs and there is active competition between the rival systems.

The Main Telegraph Office at Radio House with its high speed Wheatstone transmitters, and Undulator recorders and its efficient methods of handling traffic,

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deserves something more than a brief reference, but I must now pass on to describe the wireless terminal stations.

The transmitters keyed from Radio House are distributed between three stations :—

(1) Carnarvon—All long wave.
(2) Ongar—Some long wave and some short wave.
(3) Dorchester—All short wave beams.

Ongar Transmitting Station.

Ongar has three widely separated station buildings all originally erected for the long wave services.

One of these, known as " C " station, houses in addition, two short wave transmitters, namely :—

(A) GLQ, wavelength 27.45 m. A self-oscillator, which normally works to Madrid, Vienna and Berne, the power supplied to the anode being about 6 kw. 350 cycles unsmoothed. This transmitter is connected by a Lecher wire feeder to a single horizontal doublet aerial.

(B) GLS, wavelength 15 metres. A driven set which normally works to Cairo and Bangkok, the drive being a plain oscillator, or alternatively, crystal controlled, and the power input to the last stage of the magnifier being about 8 kw.

This transmitter is connected by a Franklin feeder system with a single broadcast aerial of the Franklin Universal type.

The four long wave transmitters we need not at present discuss.

Ongar is served with 8 land lines from Radio House, through Brentwood, in addition to two lines from Radio House direct. At present, Radio House keys 5 transmitters at once, and there are sufficient channels to easily increase this number.

Dorchester Transmitting Station.

Dorchester is an up-to-date multi-beam transmitting station. Built for one type of aerial and transmitter, it has been laid out in a well balanced and pleasing manner, and although it is the transmitting terminal point for many services, its operation is simple and efficient.

One row of five masts is erected on a line at right angles to the great circle bearing on New York.

Each of the four bays is provided with two aerial systems, one on each side of the central reflecting system so that the four bays can therefore serve eight channels.

Three of the aerial systems on the one side of the line of masts are for working with New York, and two aerial systems on the other side of the line of masts are used to communicate with Egypt.

Another pair of masts supports the aerial and reflector system for working to South America, while three further masts provide two bays, one of which has two aerials arranged back to back and a common reflector system for working with Japan and the Far East on the one side, and with South America on the other side.

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The illustration (Fig. 16), shows the seven transmitters in the station building which are employed on the following circuits :—

GLG	15·74 m.	to New York.
GLH	22·16 m.	,, ,,
GLK	37·47 m.	,, ,,
GLL	21·962 m. and 37·783 m.	,, Cairo.
GLX	15·244 m.	,, Japan or South America.
GLW	15·707 m.	,, Japan.
GLY	26·269 m.	,, Japan or South America.

FIG. 16.

Mounted on the control tables along the centre of the transmitter hall are the precision wavemeters for the various circuits, and at the end are the two monitoring recorders with a plug board by means of which the operator on duty is able to check the incoming line signal and outgoing transmitter signal on any individual circuit.

For the Japanese service, signals are sometimes sent by the Eastern route and sometimes by the Western route, by changing over from the aerial on one side of the reflector to the aerial on the opposite side.

This is done by means of a switch worked by distant control from the transmitting station which operates at the end of the main feeder near the masts, and makes contact on to one or other of the two branches which feed the two aerials. An indicator lamp at the station shows when the change over has been completed.

The Egyptian transmitter has two panels which are common for both the 21 and 37 metre transmissions, but the third panel containing the drive and two magnifier circuits is special and is changed over when the wavelength is altered.

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London is able to work all the seven transmitters at once. For this purpose, the station has five landlines and one double telephone line and the telephone line can be split and each side used for keying one transmitter while it is still used as a speaking circuit.

Brentwood Receiving Station.

The Brentwood receiving station was originally built for the long wave services, and at the present, the long wave traffic which in itself has considerable volume, all passes through this station.

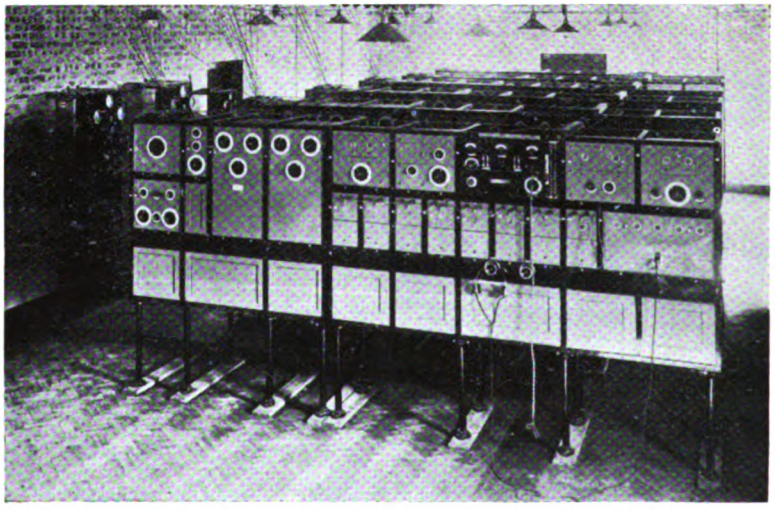

FIG. 17.

During the last few years, its short wave receiver equipment has been steadily increasing, and now the station has some 24 long and short wave receivers employed on traffic circuits which use some 60 wavelengths within the wide range of 15 m. to 30,000 m.

A bay of long wave receivers is shown in Fig. 17, and a group of some of the short wave receivers in Fig. 18.

The Brentwood aerial equipment is necessarily varied in character and illustrates the progressive changes in design which the development of new ideas is constantly bringing about.

In addition to the directional and broadcast long wave aerial systems, the station uses the following short wave arrangements :—

(A) Two wide angle beam aerials of the Franklin Uniform type, both without reflectors, one used for the 34·5 m. service to Berne and the other for the 31 m. service to Madrid, both aerials being coupled to their respective receivers by concentric tube feeders.

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(B) Three directional aerials of the R.C.A. Broadside type, which will be described later on in this paper, one for the short wave services to New York, Vienna and Beyrouth ; another for the short wave service to Bangkok and the third for the short wave services to Rio de Janeiro, Lisbon and Tokio. These aerials have parallel wire feeders.

(C) Four Broadcast Uniform type receiving aerials for general purposes with concentric tube feeders.

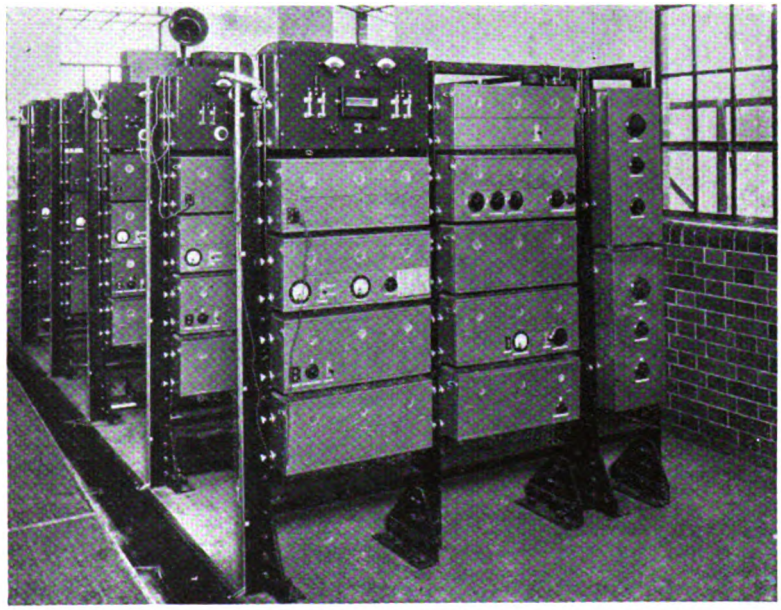

FIG. 18.

The monitoring arrangements are such that signals from any receiver can be checked on any one of three undulators or by telephone. All incoming signals sent by Radio House through Brentwood by any of the eight lines to Ongar transmitters can also be checked, as can any radiated signals from Ongar.

The silent working of this station is very noticeable. For convenience of rapid change-over, the bus-bars of the various aerial feeders run unscreened transversely over all the short wave receivers. As this might encourage the pick-up of key click induction effects caused by the working of the various relays on the station, every relay has been eliminated and replaced by a valve circuit.

Brentwood has to change its aerial-receiver connections several times a day, and it may be asked by Radio House to pick up a new or unfamiliar station. With several directional aerials to choose from, it solves the difficulty of which to employ by means of a gnomonic projection chart of the world having its centre at Brentwood,

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FIG. 19.

on which are drawn straight lines having the same angular direction as its various aerials. It can then be seen at once which aerial is the most suitable for the service concerned.

This chart is shown in Fig. 19.

Somerton Receiving Station.

Somerton is complementary to Dorchester, being a multi-beam receiving station, with two lines of masts supporting " Franklin " aerial and Reflector systems, connected by shielded feeders with the receivers.

The photograph in Fig. 20 shows eight short wave beam receivers. There are now 10 installed, and it is intended to increase this number to 16.

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The undulators of the check circuits are mounted on the bench along the middle of the room.

To economise operators' time, the tape from the undulator checking one service is fed through the undulator of a second service, so that the two records appear one above the other on the same tape. Four services can thus be recorded on two tapes, and unless one of the services is really working badly and requires close attention, it is possible for one operator to supervise both tapes and therefore four services.

FIG. 20.

In this station, all the feeders are effectively screened, and the change-over of receivers to the different feeders coupled to the various beam aerials is carried out in the specially screened feeder distribution box shown in Fig. 21.

A new box is being fitted to accommodate 24 aerials and 16 receivers.

This feature of changing aerials is a very necessary one, and may take place a dozen times a day. New York for instance may be working on six or seven transmitters, some of them running on idle tape until they are required for service, and in order to keep a watch on the signal strength of all of them in case it becomes necessary, due perhaps to faulty reception on one circuit, to ask them to go over to another, or to advise them whether signals are strong enough for traffic when it is offered on a transmitter not yet so employed, several aerial-receiver changes may be necessary.

Owing to the thorough screening and the efficient bonding to earth of all those parts in the complete receiver equipment which carry out the function of shielding the circuits, no trouble is experienced from key clicks, and relays are in use wherever necessary.

At Somerton, the problem of choosing the best directional aerial for a service is somewhat different to that at Brentwood.

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The aerials all have reflectors and they are erected to receive in directions normal to the planes of the two lines of masts, but one may wish to pick-up a station which is not on one of these particular bearings.

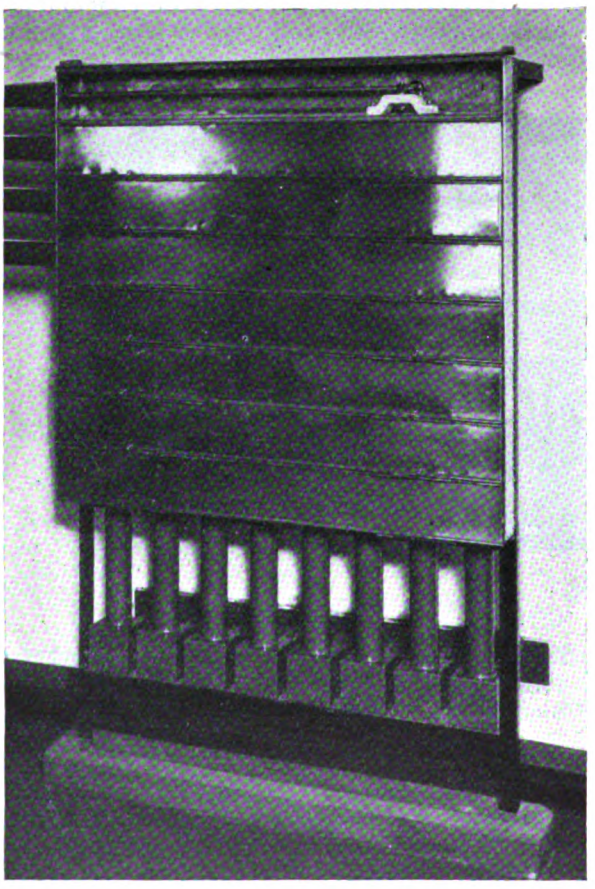

FIG. 21.

Now the polar diagram of the intensity of signals picked up by such an aerial as is well known, shows one main lobe of reception within a certain limiting angle, and on either side of this angle are nodal spaces of no signal intensity.

The first thing to determine then is the main angle of reception of the beam aerial within which there is one optimum direction, and on either side of it other directions from which the pick-up decreases as the angle increases, but which under certain conditions may still be of use for traffic purposes.

Continuing the search for signals at still wider angles from the normal to the aerial, it is found that beyond the nodal spaces there are other angles at which weak signals can be received.

There are in fact secondary lobes of reception at certain angles, the position of which, and the strength of signals received in these directions being determined by the apertures of the respective aerials in wavelengths.

When the aerial is several wavelengths wide, reception within the angle of one of these secondary lobes is so weak as to be of negligible value, but may be of a useful order if the directional aerial has a width for instance, of one wavelength only.

The chart shown in Fig. 22 is therefore employed at Somerton which enables the positions of the main lobes, nodes, and secondary lobes of the various beam aerials at their respective apertures employed on the station, to be readily determined. Lobes above the second order, when they exist, are not utilized.

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Operating Conditions.

One has to realise that outside the Imperial Beam stations, the wireless services of the whole world are inter-connected commercially, and to a large extent technically, and form practically one network. Owing to alternative routes by long, or medium, or short waves, one need never be out of touch with the corresponding station.

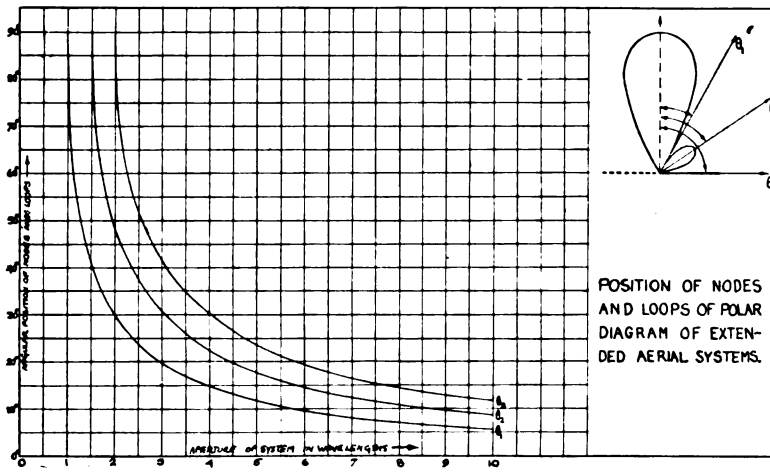

FIG. 22.

When there is not sufficient traffic to run a 24 hours service, then work is done at programme times. If traffic arrives out of programme hours, it can either be sent through a third station known to be working to the second station, or a message can be sent through the third station asking the second station to listen in for the traffic from number one.

If for any reason a particular service should break down, the outside network is there, and becomes aware of it, and is at hand if need be to carry the traffic.

The change-over from day wave to night wave does not take place until the receiving station advises that signals are failing. A station may therefore sometimes work 24 hours on its day wave.

The same transmitters which are normally working at 100 to 150 words per minute may be called on to work down to 15 words per minute twice, as is sometimes the case when starting a new service.

Wireless has the advantage that its transmitters can be switched from one service to another. For economical running of a number of short programme services, this becomes a necessity, and it is also brought about by the need to change wavelengths to avoid interference, or because of weak signals.

The New York service from Radio House is almost entirely carried on short wave, but the long wave transmitter is kept running the whole time as a stand-by on idle tape, and is available at any moment for use as an extra channel. The

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22 m. wave is usually employed to New York. If this fades during the summer, the 15 m. is used, if during the winter, the 36 m. wave is used.

Service Records.

In order to make a service pay, the economic aspect must be closely studied, and this calls for the compilation of statistics.

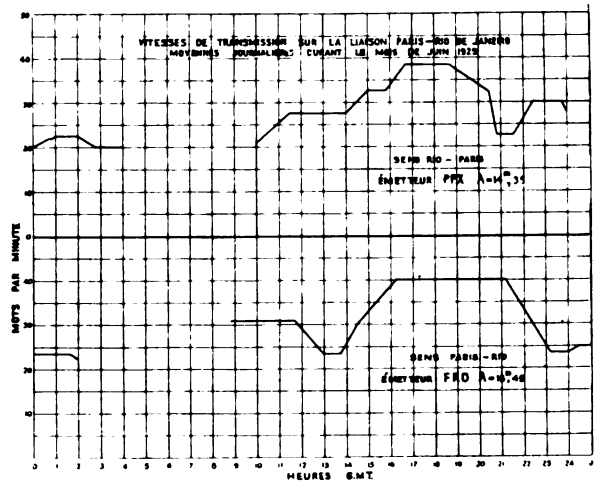
VITESSES DE TRANSMISSION SUR LA LIAISON PARIS-RIO DE JANEIRO
MOYENNES JOURNALIERES DURANT LE MOIS DE JUIN 1929
SENS RIO - PARIS
ÉMETTEUR FTA
SENS PARIS - RIO
ÉMETTEUR FTO
MOTS PAR MINUTE
HEURES G.M.T

FIG. 23.

We can start our records for instance by noting the Wheatstone transmitter tape speeds in five letter words per minute for the 24 hours.

This can be extended, as in the charts of the Paris-Rio service kindly sent me by the Cie Radio France, which give the hourly speeds for the 24 hours, averaged for a complete month (Fig. 23). These curves show the average rate of the outgoing traffic on 15·45 m. and the average rate of the incoming traffic from Rio to Paris on 14·35 m.

The mean speed during the working hours for the whole month of June is seen to be about 30 words per minute.

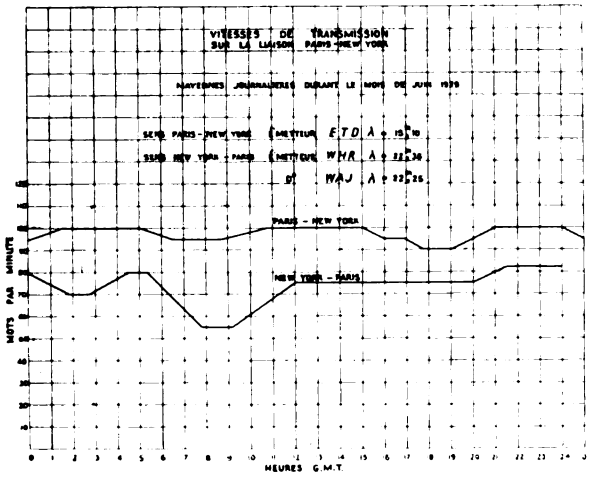
VITESSES DE TRANSMISSION
SUR LA LIAISON PARIS-NEW YORK
MOYENNES JOURNALIERES DURANT LE MOIS DE JUIN 1929
SENS PARIS-NEW YORK ÉMETTEUR FTD
SENS NEW YORK-PARIS ÉMETTEUR WHR
WAJ
PARIS - NEW YORK
NEW YORK - PARIS
MOTS PAR MINUTE
HEURES G.M.T

FIG. 24.

A further example of the same type is afforded by the Radio France chart of mean traffic speeds on the Paris-New York service, also for the month of June last (Fig. 24). In this case, the outgoing traffic is sent at a mean rate of about 97 words per minute, and the incoming traffic is received at a rate of about 73 words per minute.

But it is unusual for traffic to be sent during the whole of this time, periodically the transmitters are run on idle tape while they are waiting for traffic.

This has given rise to another form of chart in use

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at Radio House, on which is recorded the percentage time each hour of the 24 that the transmitter is actually sending traffic on a given service, with notes to indicate what it is doing during the remainder of the time.

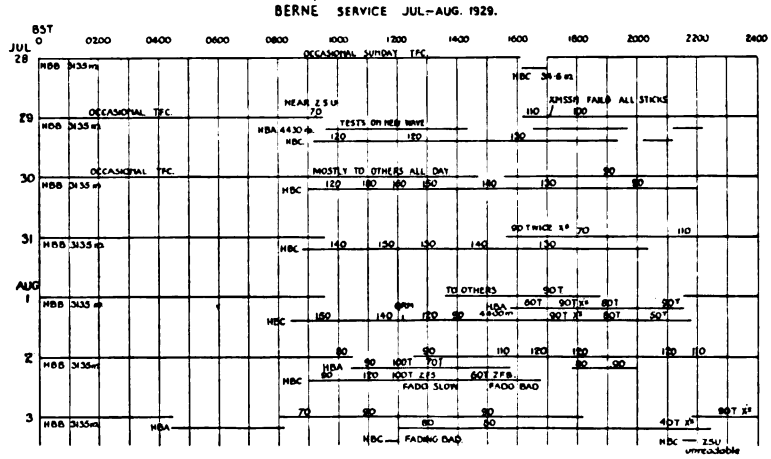

FIG. 25.

One transmitter may be used for instance on several part time services. As traffic increases during the day, so the stand-by transmitters come into use, or perhaps due to strong atmospherics on a long wave, a change-over is made to a short wave transmitter, or because of interference or fading on one short wave transmitter, a change-over is made to a transmitter sending on another short wave which is not so affected.

Records of these changes of call sign and wavelength on any given service are noted at the receiving station, and a typical chart of this character from Brentwood showing the transmitters employed at Berne during one week on the Berne-London service is shown in Fig. 25.

In general, this chart indicates the number, call signs, and wavelengths of the transmitters in use during the rush hours, that is when the circuit is working under full service conditions. To meet the traffic demands some of these transmitters may have been deflected from other services. Some transmitters therefore work on short time, others on practically a 24 hour load.

It therefore becomes necessary to keep a record of the number of hours each transmitter is actually sending traffic, and a table of this character for the transmitters used on the " Via Marconi " services during the month of June, 1929, is shown below.

It will be noted for instance, that the best load factor is still held by a long wave transmitter, namely GLP, the 5,332 m. set at Ongar, which during the month had an average working day of 12·6 hours.

Another chart records the average hourly speed of short wave transmission and reception taking into account that the transmitter may be occupied during part

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Circuit.	Normal Transmitter.	CARNARVON.			ONGAR.						DORCHESTER.						
		GLC	MUU	GLJ	GLB	GLA	GLO	GLP	GLQ	GLS	GLH	GLG	GLK	GLW	GLY	GLL	GLM
		H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.	H.M.
New York ... (Ph'grams) ...	GLH GLK	99.8	87.38	—	—	—	—	—	3.35	—	238.24	9.10	5.55	—	—	—	—
	MUU GLC	3.30	—	—	—	—	—	—	—	—	26.40	19.20	2.35	—	—	—	—
Paris	GLB	—	—	—	190.14	80.18	25.10	8.14	.55	—	—	—	—	—	—	—	—
Berne ...	GLA	2.20	8.20	4.55	.10	222.59	34.32	42.25	3.15	—	—	—	—	—	—	.25	1.0
Madrid ...	GLO	—	—	—	—	3.7	131.45	28.4	48.18	—	—	—	—	—	—	—	—
Barcelona ...	GLO	—	—	—	—	—	82.39	18.12	21.34	—	—	—	—	—	—	—	—
Vienna ...	GLP	—	—	—	—	7.15	29.59	112.24	121.2	—	—	—	—	—	—	.20	—
Belgrade ...	GLP	—	—	—	—	—	—	74.5	—	—	—	—	—	—	—	—	—
Buenos Ayres...	GLW GLY	—	—	—	—	—	—	—	2.22	—	—	—	—	81.27	22.49	—	—
Rio de Janeiro	GLW GLY	—	—	—	—	—	—	—	—	—	—	—	—	24.50	6.56	—	—
Moscow ...	GLP	—	1.3	—	—	—	—	91.27	14.37	—	—	—	—	—	—	—	—
Lisbon ...	MUU	.25	93.15	—	—	1.17	—	4.56	—	.40	—	—	—	—	—	—	—
Stamboul ...	GLC	28.32	.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cairo	GLL GLM	—	—	—	—	—	—	—	5.0	68.6	—	—	—	—	—	63.11	17.52
Beyrouth ...	GLL GLM	—	1.20	—	—	—	—	—	.10	.16	—	—	—	—	—	46.54	9.52
Bangkok ...	GLS	—	—	—	—	—	—	—	—	55.53	—	—	—	—	—	.37	—
Total		133.55	191.43	4.55	190.24	314.56	304.5	379.47	220.48	124.55	265.4	28.30	8.30	106.17	29.45	111.27	28.44

of the hour only, while the average speed is calculated over the whole hour. All these traffic results are analysed and serve as a helpful guide for the introduction of further improvements into the operating organisations.

Under certain conditions it may be found more economical to use many slow speed transmitters on a service instead of running a few at high speed, and it may happen that several hundreds of miles of poor landline between the Central Telegraph Office and the transmitting station rule out the use of high speed keying; each traffic organisation has its own problems and must decide them for itself and it is not intended in this paper to do more than point out what are the actual conditions of working of the wireless services to-day.

The value of Monitoring.

Much of the success of a commercial wireless service depends on the efficiency and effectiveness of the monitoring. If the quality of signals falls off, the operator whether at the Central Telegraph Office or Radio House is only in a position to recognise faults due to bad keying or badly punched tape the other end, if it is due to any other cause than faulty transmission, he concludes the conditions are worse, and he is inclined to ask for the message to be sent twice—which drops the effective speed to half—or alternatively, for the operator to send at a lower speed.

The monitory operator on constant watch at the receiving station, however, is immediately able to diagnose the trouble, whether it is due to atmospherics, fading, echo, or jamming, or some fault in the apparatus or landline link.

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He saves traffic time by indicating the source if it is at his end of the channel, and can often minimise it or clear it altogether by balancing adjustments on his receiver, or by advising a change of wavelength if the source is to be found in changes which are taking place in the physical conditions of the intervening medium between the two stations, or by interference from some other transmitting station.

The cost of monitoring is more than made good by the higher speeds of transmission which are maintained in consequence, and its actual cost is not great when it is considered that a traffic speed of 150 words per minute on for example an Empiradio beam service, every yard of tape scanned by an operator carries a message value of about £1.

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THE MARCONI TUNING FORK AS A FREQUENCY STANDARD

For many purposes in connection with radio work it is essential that reliable tone generators should be obtainable in order to provide standards of frequency to which other frequencies may be referred.

All accurate frequency measurements depend, in the first place, on an accurately adjusted fundamental frequency, the source of which depends on the band of frequencies involved.

The frequency spectrum may be divided into the following rough groups, as far as radio purposes are concerned.

(A) 50—3,000 *cycles. For this range a tuning fork is generally employed where a stable oscillator is required.*

(B) 3,000—10,000 *cycles. Magneto-strictive oscillators are useful for these frequencies.*

(C) 10,000—75,000 *cycles. For reliable oscillations of from* 10,000 *cycles upwards stabilised Inductance Capacity valve oscillators are generally employed.*

(D) 75,000—3,000,000 *cycles. Either* (1) *Piezo-electric crystal controlled oscillators or* (2) *Valve oscillators may be utilised in this range.*

(E) *Above* 3,000,000 *cycles. Valve oscillators are the only form of oscillators which can be practically employed at frequencies above* 3,000 *kilocycles.*

To cater for the band of frequencies from 50 *to* 3,000 *cycles the Marconi Company has evolved the tuning fork and associated apparatus to be described below.*

The chief applications of this tuning fork are :—

(1) *It can be applied directly as a control for the automatic synchronisation of facsimile systems.*

(2) *It can be employed as a control of the frequency of radio transmitters, when the fundamental frequency of the fork has been suitably multiplied.*

THE Tuning Fork Oscillator has been developed as a means of securing a source of oscillations of extremely constant frequency. It is suitable for purposes for which a constancy closer than 1/100,000 is required.

The Marconi Tuning Fork Oscillator is capable of such a degree of accuracy, and comprises a mild steel Fork which is maintained at a constant temperature in an Incubator or heating chamber fitted with a very high grade temperature control.

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Tuning Fork.

The material ordinarily used for the Marconi Forks is a special grade of very uniform mild steel, which is fully annealed in the course of the manufacture of the fork. The exceptional uniformity both of the material and of its physical condition

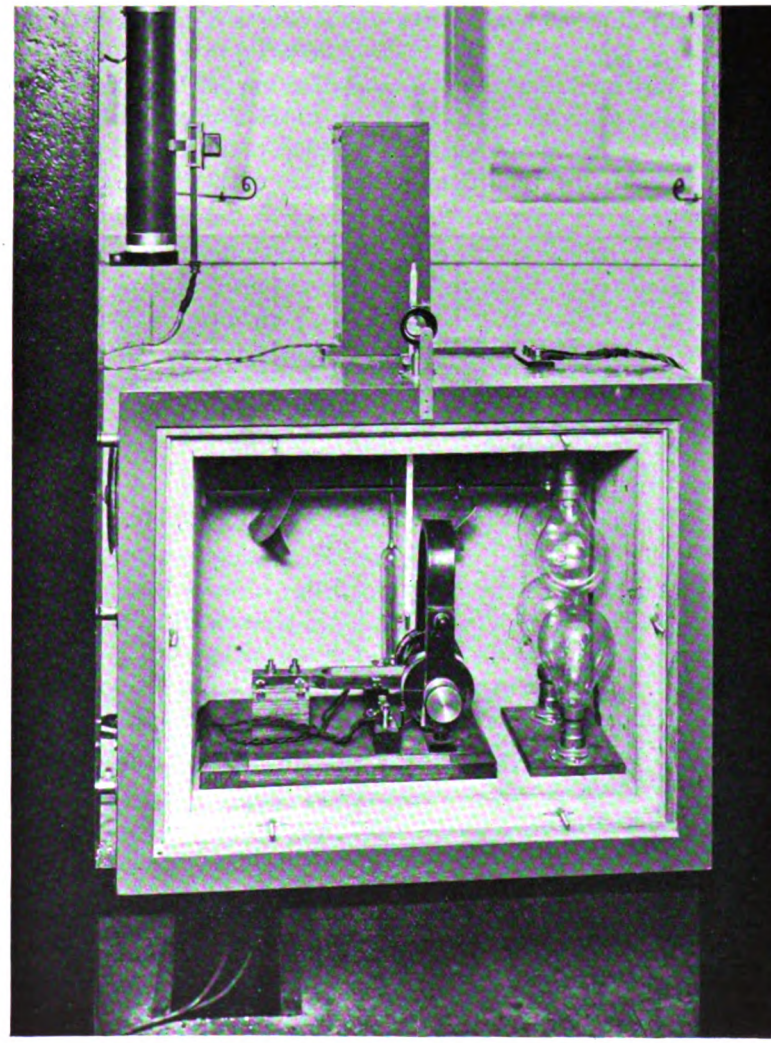

FIG. 1.

ensures great permanence in the frequency of the finished fork. In a fully annealed

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state, this material has exceptionally small internal friction under small periodic stresses, such as occur when a tuning fork vibrates with small amplitude. The finished fork has, in consequence, a very low decrement, a feature of importance in a fork which is used as the master frequency control of an electrical system.

The shape of the fork is in some respects a departure from previous practice. It has been specially designed by ourselves with a view to obtaining exact mechanical balance between the prongs with the object of reducing to a minimum the reaction of the butt of the fork on its support. Special attention has been paid to the attachment of the fork to its support, and to the nature of the support itself. These factors are of importance for reducing to a minimum the effect of the support on the frequency of the fork and particularly its effect on the constancy of the change of fork frequency with temperature.

The saddle which holds the butt of the fork is mounted on a Fork Driving Base in such a position that the prongs of the fork are near pole pieces consisting of bundles of iron wire, which are polarized by a permanent magnet. Mounted on these pole pieces are two coils of wire, one of which serves to transfer the impulses originating from the fork, to the grid of the first valve of a valve amplifier, while the other coil drives the fork by means of impulses derived from the plate circuit of the last valve of the amplifier.

The circuits employed are specially designed to render the fork frequency as independent as possible of such factors as battery voltages, etc.

Before proceeding to a description of the incubating arrangements, it may be mentioned that nickel chrome steels, such as Elinvar, have been used for forks in certain cases, in preference to mild steel, owing to their smaller change of frequency with temperature. These steels have certain disadvantages owing to their peculiar physical properties. Changes in the physical properties of these steels resulting from a change of temperature do not follow the change of temperature immediately. There is a time lag resulting in a slow progressive change in frequency which may be perceptible for weeks.

Incubator and Thermostat.

To attain a high degree of constancy of frequency in a fork made either of mild steel or of nickel chrome steel, it is necessary that the fork should be maintained at an even temperature by means of a high grade incubator. The incubator consists of a heat-insulated wooden box containing the Tuning Fork with driving magnet, and a Thermostatic regulator having a glass bulb containing Toluene, a stable liquid having a high co-efficient of expansion with temperature. The expansion and contraction of the Toluene actuates a Mercury column in a capillary tube fitted with electrical contacts which form part of the grid circuit of a triode valve. The temperature inside the Incubator is maintained at a predetermined value (about 140° F.) by means of heating lamps fitted in the Incubator. These heating

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lamps are so adjusted that, if they are left continuously in circuit, the temperature of the chamber will rise above the operating value. On the temperature of the chamber reaching this value, however, the Toluene regulator is so adjusted as to close contacts in the grid circuit of a control valve (thereby applying a negative potential to the grid of the valve). Connected in the anode circuit of the valve is the operating coil of a sensitive relay, the contacts of which make and break the heating lamp circuit. On the closing of the contacts of the Toluene regulator, the contacts on the Thermostat relay are arranged to "break," thus switching off the heating lamps. A Rheostat in series with the heating lamps is so adjusted

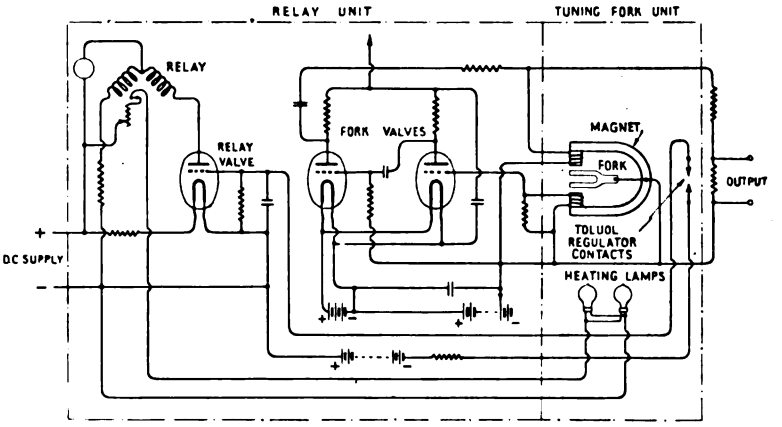

FIG. 2.

that the periods when the lamps are "on" and "off" are approximately equal, and the Thermostat relay is actuated at intervals of a second or so. In order to avoid a temperature gradient in the heating chamber, a motor-driven fan is provided which vigorously stirs the air in the chamber. The incubator heating lamps are provided in duplicate, a simple change-over switch being provided for changing from one set of lamps to the other in the event of a lamp burning out. The temperature of the chamber can be observed by means of a Thermometer which projects from the top of the chamber, a magnifying glass and peep-sight being provided to facilitate accurate reading.

The anode circuit of the Fork Driving Valve includes a resistance across which is obtained an oscillatory potential having a frequency identical with that of the tuning fork. Provision is made for coupling this circuit through a Triode "Frequency Selecting Valve," to a closed resonant circuit which is tuned to either the frequency of the fork or to a multiple of that frequency according to the purpose for which the Tuning Fork oscillator is required.

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This Frequency Selecting Valve is arranged to give an output wave form which is rich in harmonics, to one of which the resonant circuit is tuned.

This circuit may be followed by one or more stages of amplification, with or without frequency change, as may be desired for any particular purpose.

The Marconi Tuning Fork Oscillator is pre-eminently suitable for all purposes where an extremely constant frequency source is required whether the frequency be of the order of audio frequencies or radio frequencies, the principal difference in the equipment for the two types being in the number of stages of subsequent amplification and frequency change.

The standard arrangement of the equipment consists of vertical steel racks carrying the various units.

Thus the heating chamber containing the fork may be mounted in the lower section of a rack, above which are mounted the relay unit, containing the thermostat relay and driving valve, and the control unit mounting the necessary switchgear for the supply to the fan motor and valve filaments and anodes and the relay feed milliammeter.

The equipment can be supplied for operation from either D.C. or A.C. supply mains as desired. In the case of the A.C. equipment, rectifying valves, with the requisite filament and anode transformer, are fitted in the relay unit for supplying D.C. to the valve anodes and the relay.

The total power taken from the mains is of the order of 250 watts.

A photograph of the complete mounting is shown in Fig. 1 and a typical diagram of connections of the Tuning Fork Oscillator in Fig. 2.

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A CONSTANT FREQUENCY CONTROL FOR BROADCAST TRANSMITTERS.

In the previous article a description of a thermostatically controlled tuning fork, manufactured by the Marconi Company, was given, and in the following pages the application of such a fork to the strict control of transmitter frequencies will be discussed. All such controls are similar in general principle in that they consist of stabilised oscillators of relatively low power which drive the main transmitter oscillator.

In the control to be described below, the fundamental frequency of the tuning fork is multiplied to give the required frequency for the transmitter.

The very high degree of accuracy of frequency rendered necessary by modern transmission conditions calls for the increasing use of such controls, especially on any of the shorter wavelengths.

An excellent example of such a case is the simultaneous transmission of the same signals by stations working at an identical frequency. In this type of arrangement any discrepancy between the radiated frequencies would cause an unintended heterodyne, and so render the reception of the signals unsatisfactory. The B.B.C. relay stations, which radiate identical frequencies, and are each controlled by a tuning fork, provide evidence of the accuracy obtainable. It may be noted that in the case cited an error of 1 in 20,800 in any one tuning fork would cause a heterodyne note of 50 cycles per second, while in actual experience the heterodyne between the stations rarely attains so great a value as 15 cycles per second.

A TUNING fork of fixed frequency, which can be chosen between 700 and 1,400 cycles, is taken as the standard frequency source This fork is maintained by a tuning fork drive circuit whose output is amplified and its frequency is doubled ten times, thus giving a final output frequency of from 700 × 1,024 to 1,400 × 1,024 or from 716·8 kc. to 1,473·6 kc. according to the frequency of the fork. This corresponds to a final wavelength range of from 203·5 to 418·5 metres approximately, while other wavelengths involve the addition or elimination of doubling stages. The general layout of the apparatus is shown in Fig. 1.

Tuning Fork and Thermostat.

The tuning fork and thermostat is similar in construction to that used in connection with the facsimile apparatus and described in the previous article. A photograph of the actual fork employed in this apparatus is shown in Fig. 2. A toluol-mercury thermostat is used to regulate the temperature, and this thermostat and its associated relay equipment, etc., are very similar to the corresponding components in the facsimile apparatus.

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The actual frequency of the fork is, of course, fixed by its physical properties and dimensions, but this frequency can be varied very slightly by adjustment of the working temperature and of the valve voltages, *i.e.*, plate voltage, grid voltage, and filament voltage in the tuning fork drive circuit. Any fork can be supplied within the frequency limits given above, for which range of frequencies the doubling circuits, etc., have been designed.

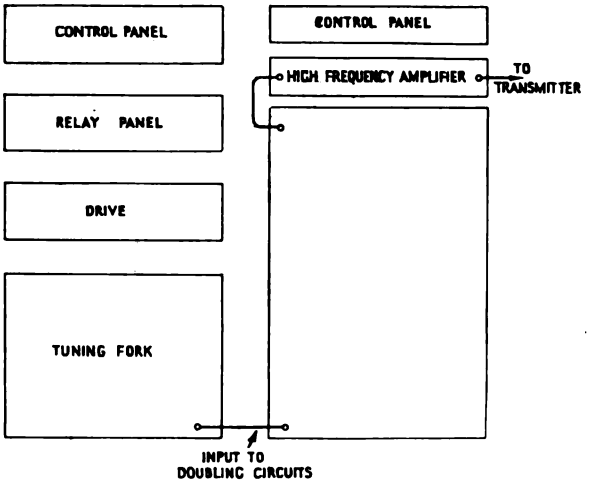

FIG. 1.

The fork is enclosed in a heat insulating box, which is also electrically screened by a copper covering. As will be seen on reference to Fig. 1, the relay box is mounted above the fork box, and consists of the circuits and relays which switch the heater lamps on and off. The air in the fork box is kept constantly stirred by means of two fans at the back of the box, and the temperature of this air stream is maintained constant to within about 0·1°F. in this manner.

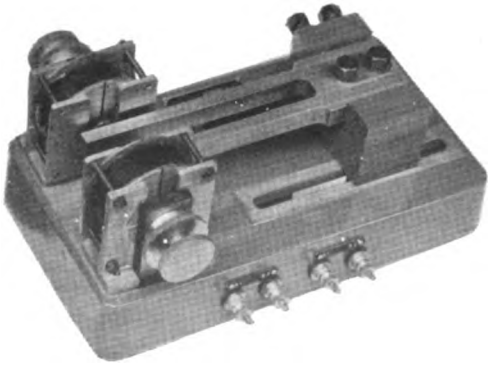

FIG. 2. *Marconi Tuning Fork.*

Tuning Fork Drive.

The circuit diagram for the tuning fork drive is shown in Fig. 3, and will be seen to consist of two tuning fork maintaining valves, resistance capacity coupled, and one stage of transformer coupled amplification.

The frame of the tuning fork is connected to earth, and to one side of one of the maintaining coils. The other coil is in the grid circuit of the first valve, and the anode of this valve is connected to the grid of the next valve in the usual way throngh a condenser. This condenser fulfils two functions: It

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couples together the grid and anode circuits of the valves, and also ensures that the currents shall be in the correct phase. Its value is approximately ·01 ufd.

The next valve has its output taken through a condenser and a potentiometer to earth. The potentiometer is calibrated roughly in T.U's and serves to adjust the output of the entire drive. The tapping from this potentiometer is taken to the

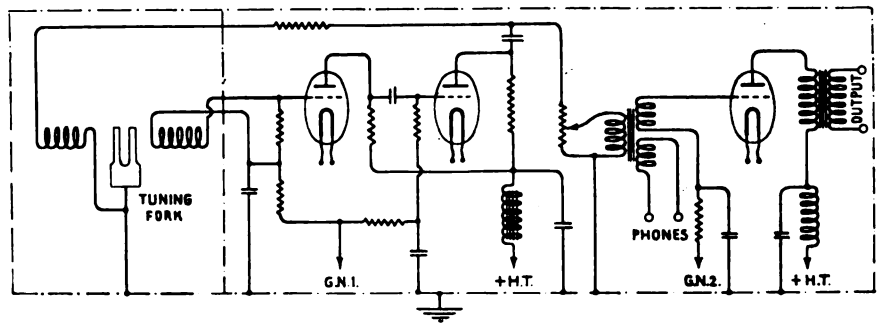

FIG. 3.

primary of the intervalve transformer, and the next valve is coupled to this in the normal way. A listening point is provided at this stage. Arrangements are made to ensure that the inclusion of the telephones in the circuit do not disturb the output of the drive.

The actual line of demarcation between the fork box circuits and the drive box circuits is shown in the diagram as a dotted line.

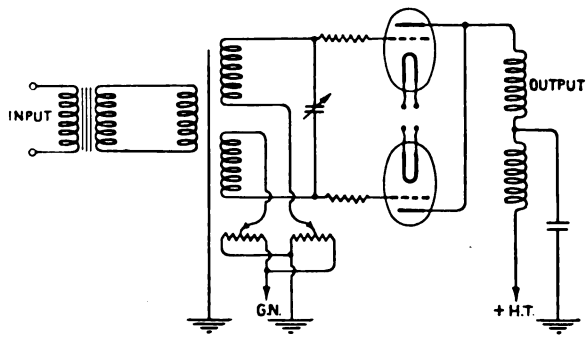

FIG. 4.

The output from the drive to the doubling circuits is shown on the extreme right, and consists of an iron core transformer in the anode circuit of the last valve.

Frequency Doubling Circuits.

The output from the tuning fork drive is taken through a lead covered cable to the input stage of the frequency doubling circuits. A typical stage of doubling consists of an input transformer with a split secondary, a secondary winding tuning

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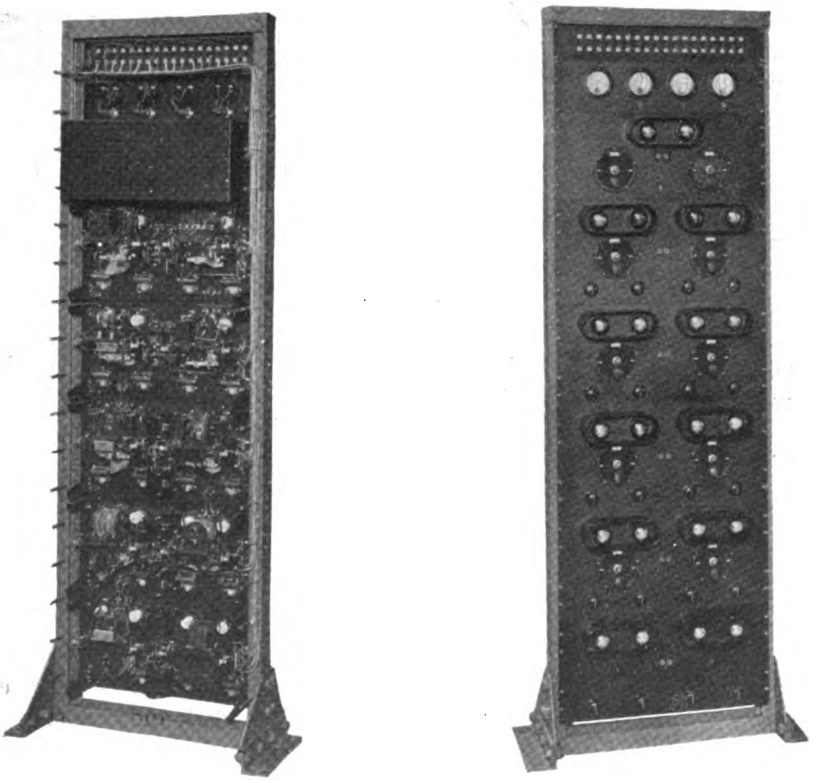
condenser, two valves with a push-pull input and parallel output, and grid negative and high tension feeding circuits. The circuit diagram for one of these stages is shown in Fig. 4.

The valves are set at their rectifying point, which operation is carried out by means of the controls, as will be described later. The form of circuit employed has the advantage that only the even harmonics are passed.



Frequency doubling circuits (back and front view).

The question of the design of the input transformers presented much difficulty, as all frequencies from approximately 1,400 to 1,500,000 cycles had to be dealt with, and transformers which were suitable for the former were useless in the case of the latter frequencies. Further, the voltage amplification between the primary and tuned secondary had to be kept within certain limits.

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Ultimately the form of transformer shown in Fig. 5 was adopted in the case of the lower frequencies, and consists of a primary of one section, block wound with stranded wire, and a secondary of two sections, mounted on each side of the primary also block wound with the same type of wire. All the sections are screened from each other by means of copper gauze, which is broken to avoid short circuited turn effects.

In the case of the higher frequencies, the transformer consists of two secondary sections mounted side by side on an ebonite tube (Fig. 6) The primary sections are block wound on an ebonite rod passing through the centre of this tube, and supported by means of two screws at its ends. These two screws allow of the adjustment of the primary section with respect to the two secondary sections in order to obtain the best balance, etc. In the case of these transformers, the shielding is of copper sheet broken in a similar manner to that already described.

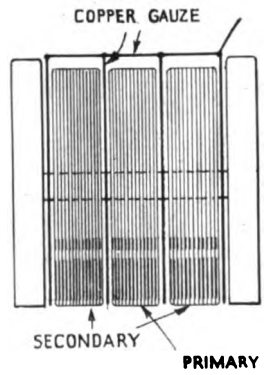

FIG. 5.

All the grid connections and the connections between the transformers and the condensers are made with special shielded wire to reduce interaction effects, etc., and the screens of the transformers are bonded to earth.

Since any alternating voltage across the direct current supplies to a doubling stage will be fed to the two valves in parallel, it will appear in the output. The next stage of doubling will then act as a modulator, and the final output frequency will be modulated by the alternating voltage across the direct current supplies. To avoid this most

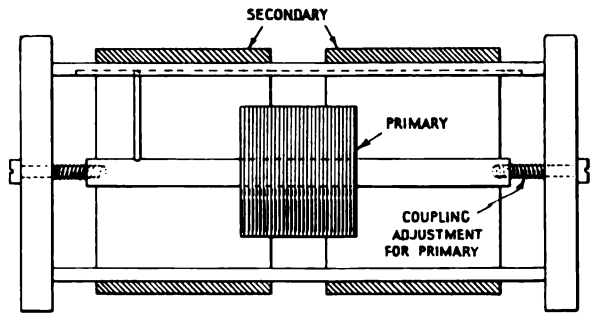

FIG. 6.

undesirable feature, all direct current supplies to each doubling stage are carefully

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blocked—the grid supplies by resistance-capacity, and the anode supplies by choke-capacity in the earlier stages, but resistance-capacity in the later stages.

In all, ten stages of doubling are employed, thus giving a frequency multiplication of 1,024 as has been stated before.

All the frequency multiplying apparatus is contained in an iron framework and is suitably screened.

Control Panel.

The control panel is mounted at the top of the doubling circuits, and includes three voltmeters for the measurement of High Tension, Low Tension and Grid Negative respectively, and a milliammeter for the correct adjustment of the valves in the doubling circuits. This milliammeter may be plugged into any pair of valves, and the valves may be adjusted either :

(1) By removing one valve and adjusting the grid negative on the other to give a suitable indication of anode feed with the working input, and then putting in the other valve and adjusting this in the same way ; or

(2) Putting excess grid negative on both valves and reducing this for each valve in turn until each begins to show a slight anode current with no input.

On the control panel are also mounted all the fuses. Three fuses—one for H.T., one for G.N., and one for L.T.—are provided to each set of four valves, and three main fuses are also permanently in circuit.

Final Amplifier.

The output from the multiplying circuits is taken to a transformer with tuned secondary, and through one stage of push-pull amplification to the main transmitter.

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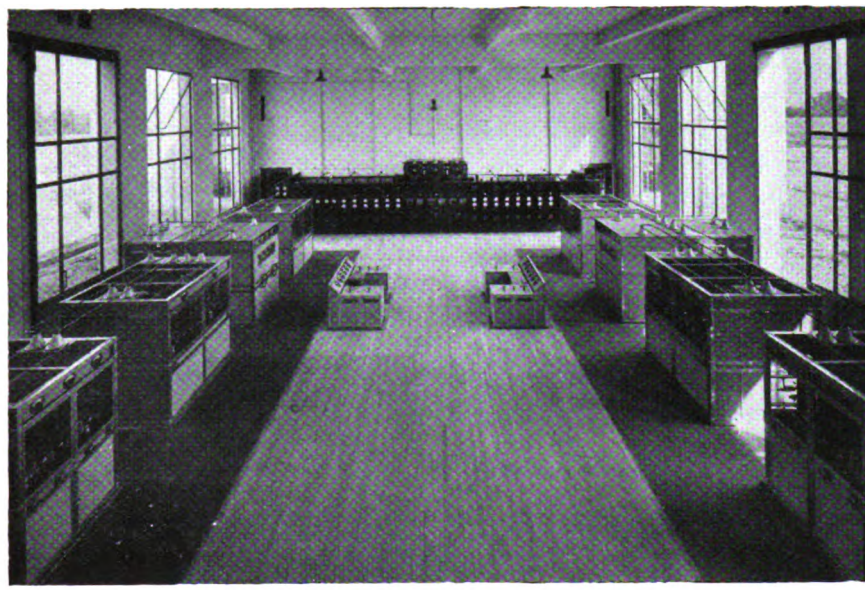
MARCONI NEWS AND NOTES

BRITISH REGIONAL BROADCASTING.



A general view of the transmitter hall at the new B.B.C. station at Brookman's Park.

As foreshadowed in THE MARCONI REVIEW, No. 12, Brookman's Park Regional Station has now taken over the entire transmission of the London broadcasting programmes. Thus 2LO changes its home for the third time and enters on what may now fairly be expected to constitute its permanent quarters.

The call sign 2LO was originally allotted by the British Government to the Marconi Company for its experimental transmitting station at Marconi House and was used to identify the first regular broadcasting programmes transmitted by the Marconi Company from London—as distinct from their earlier broadcasting from Writtle—in the spring of 1922.

In March 1925 the second 2LO, again manufactured by the Marconi Company, was opened by the British Broadcasting Company—now the British Broadcasting Corporation—on the roof of a well-known London store in Oxford Street. The transmitter at Marconi House was, however, retained as a stand-by and until very recently its voice was still heard on the air at regular intervals when tests were made to ensure its constant readiness in case of emergency.

At length, however, its work is concluded after more than seven years of sterling service in the new art and science of broadcasting, and early listeners will learn with

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regret that the veteran transmitter has now been dismantled. As a matter of historical interest, we reproduce a photograph of the Marconi House broadcasting transmitter as it was in its earliest days. A comparison with the Marconi P.B. transmitter, illustrated on page 26 of THE MARCONI REVIEW, No. 12, and with the photograph of the Brookman's Park transmitter, published on page 27, indicates the progress that has been made in the design of broadcasting transmitters during the last eight years.

The B.B.C. station at Oxford Street embodied the experience gained in the operation of the first London station at Marconi House, and during the years of its active life it participated with marked success in many famous broadcasts, as well as maintaining with remarkable efficiency and reliability the daily transmissions of the regular programmes.

Success of the new 2LO.

The new transmitter at Brookman's Park, which took over the London programmes on the afternoon of October 21st, in its turn embodies the result of experience gained in the operation of the other broadcasting stations that have been transmitting programmes daily for some years past. The new station is operated on an aerial power of 30 kilowatts compared with the 2 kilowatts of the Oxford Street station. Despite some prophecies of difficulties that might occur on account of the greatly increased power and the changed location of the station—now situated 15 miles from the centre of London instead of in the heart of the West End—the change-over was effected with the minimum of inconvenience to the listening public, and a high degree of popularity has already been won by the new transmitter, which was manufactured by the Marconi Company in accordance with the special requirements of the B.B.C.

An eloquent testimony to the constancy of the transmitter is the fact that there have been no complaints that the station interferes with its neighbours in the wavelength plan, even though its power is about 30 kilowatts in the aerial.

Newspaper and public comments on the performance of the station demonstrate that it will amply fulfil its object of improving the broadcast service to listeners over a very wide area.

Reports on Reception.

The following published reports are typical of many which describe the excellent results obtained from the new transmitter.

> "Previously it had been observed that London was rather difficult to tune owing to the patent variable condenser contained in the receiver, but Brookman's Park has put an end to that. Much less reaction is required."
>
> "Until the new station, reception on 2LO was normal but without real 'kick,' combined with annoyance from a Continental heterodyne. The test, however, revealed a good increase in signal strength which of itself smothered the foreigner, producing a much happier state of affairs."

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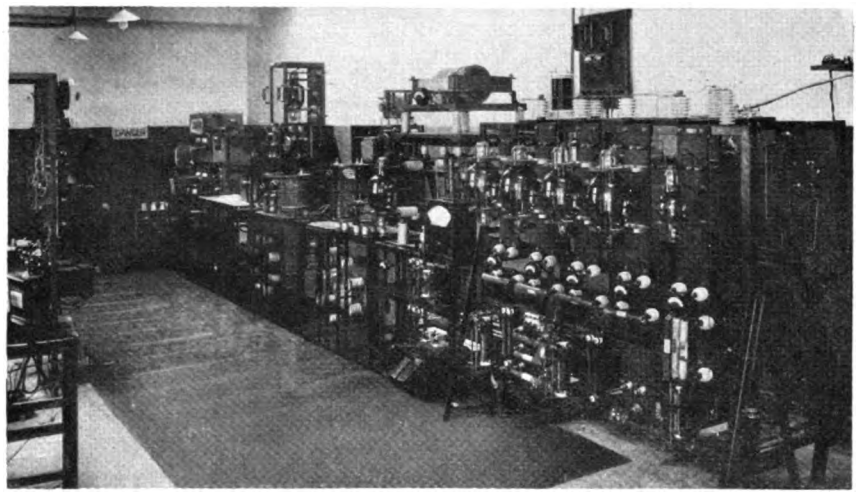

The first 2LO at Marconi House.

"The reception from Brookman's Park on this set (portable) was fine, with excellent volume. The tuning band was only spread over four degrees of the condenser scale."

"This new 2LO is the first of five similar stations which the B.B.C. are setting up in different parts of the country. When eventually they are working, Britain will have—in the Regional Scheme—the most perfect system of broadcasting in the world."

"Wide enquiries suggest that the general feeling is that the new 2LO has proved its worth and is an improvement."

"Great improvement, can easily tune in 5GB. Stuttgart, 4 metres above 2LO, is heard more easily than before. Graz, 4 metres below 2LO, was also received—an impossibility under the old conditions."

"Within ten miles as the crow flies, but not the slightest difficulty in getting any station required."

Benefit to Crystal Users.

"Crystal users situated between 20 and 30 miles from London, who have hitherto heard only a whisper, are now delighted with the volume they are getting, and districts even up to 80 and 100 miles from Brookman's Park are reporting good reception on a crystal set."

"With a two-valve set a complete amateur tuned in at good strength, and easily found also 5GB clearly and without interference.

"Reports from listeners indicate that reception is generally improved over a large area."

"Criticism of the new Brookman's Park broadcasting station has brought forth a host of letters to the B.B.C. from satisfied listeners, praising the improved quality and greater volume which they are getting."

"Reports from all districts indicate that thousands of new listeners are now able to enjoy the programmes from 2LO for the first time. It is estimated

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that nearly 3,500,000 listeners are being satisfactorily served by Brookman's Park."

"Hundreds of letters have been received from listeners who have picked up these transmissions, but only eight of them make complaints. Many outside the area which the new station is intended to serve heard the transmissions and the B.B.C. received compliments from the north of Scotland, South Wales and the Isle of Skye—and even from Amsterdam."

Reception on the Continent.

The Berlin correspondent of one of the principal British wireless papers wrote as follows :—

"Thanks to the Brookman's Park station listeners in the Berlin and Konigswusterhausen areas are able once more to hear with ease the London programmes, reception of which (mainly from Daventry) had been rather interfered with since readjustments under the Brussels and subsequent Plans. In spite of the narrow separation between London and its two neighbours, Graz and Stuttgart, the new station gives excellent loud speaker results, and the average strength is above that previously noted from Daventry."

Reliability of British Broadcasting Stations.

An article on "The Technique of Broadcasting," published on October 11th in *World Radio*, an official publication of the British Broadcasting Corporation, contains some further information with regard to valve life.

With regard to the average life of water-cooled valves in use at 5XX, 5GB and Brookman's Park, the writer states that while "6,000 hours is about the average life of the rectifiers, two rectifiers at 5XX recently completed their useful life after both had done over 10,000 hours work. The average for modulators and magnifiers is about 4,000 hours, but two modulators at 5XX have done over 10,000 hours."

As Marconi valves are used at 5XX, 5GB and Brookman's Park, this is another gratifying tribute to the robustness of Marconi valves, which, it should be noted, are always rated on a conservative basis.

The general reliability of the British broadcasting stations as a whole is very high, as is shown by further figures given in the article in question. It states that the hours of transmission from the British Broadcasting Corporation's stations increased from 46,215 hours in 1925 to 64,467 hours in 1928, and in the same time the breakdown percentage, which is an indication to the efficiency of the service, has been reduced from 0·9 per cent. to 0·03 per cent., which means that in 1928 the breakdown totalled only 19 hours 2 minutes, or approximately 58 minutes per station.

This report is very creditable to the manufacturers who have supplied these broadcasting installations; further, the dependability of Marconi broadcasting stations is now recognised throughout the world as is shown by the increasing number of orders that have recently been received by the Marconi Company from many countries for this type of apparatus.

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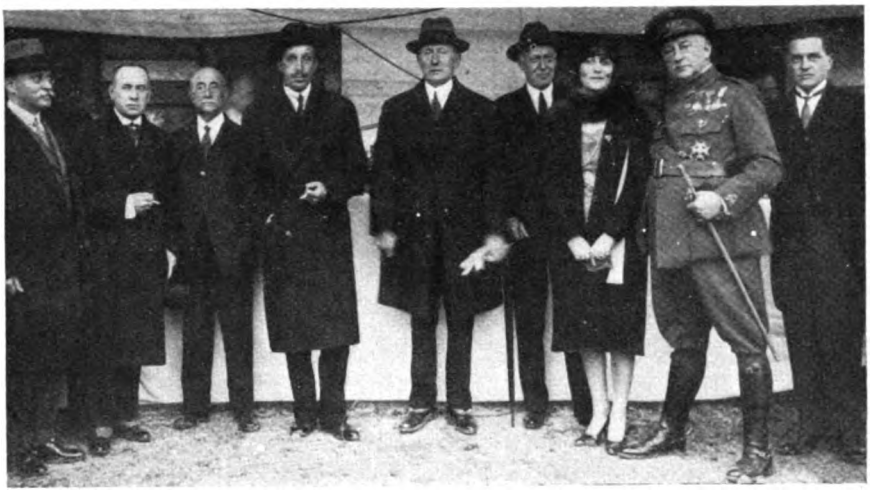

An interesting photograph taken at the opening of the Aranjuez group of wireless stations. Next to His Majesty the King of Spain (centre) are the Marchese Marconi, the Marquesa Marconi, and (on the right, in uniform) General Primo de Rivera.

New Spanish Stations.

Marconi apparatus is extensively used in the important new group of wireless stations which were opened on October 21st by the King of Spain at Aranjuez, near Madrid, in the presence of the Marchese Marconi, the Spanish Prime Minister, and Ambassadors representing other countries.

This group of wireless stations has been designed and built to extend the range of Spanish external communications having regard to Spain's importance in the commercial life of the world and particularly of South America. Madrid is now placed for the first time in direct wireless telegraph communication with both North and South America and, by means of the Marconi short wave Beam installation which is included in the equipment of the Aranjuez station, a regular commercial telephone service between Spain and the Argentine Republic will be available in addition to high-speed Beam telegraph services.

For use in these circuits special receivers have been constructed by the Marconi engineers on behalf of Transradio Espanola, the Spanish Company to which these stations belong and which carries out the wireless telegraph services between Spain and other countries.

The supply of this apparatus to Transradio Espanola is the second big order for British wireless equipment recently received from Spain, the Marconi Company having also supplied a short wave station to the Spanish Government to establish a direct wireless service between Madrid and the Spanish colony at Fernando Po, in equatorial Africa.

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The Canadian Marconi Company's Beam receiving station at Yamachiche, near Montreal.

Beam Telephony.

The British Broadcasting Corporation's broadcast of the Armistice Day Service at the Cenotaph, London, on November 11th, was successfully relayed by Beam telephony from England to Canada and re-broadcast by a chain of stations throughout the Dominion.

A sound record of the ceremony was picked up by the microphones in Whitehall, and, in addition to being transmitted by all the B.B.C. stations, was carried by landline to the Imperial and International Communications Company's short wave Beam station at Bodmin. Thence it was transmitted by means of the Marconi-Mathieu Multiplex system of telephony to the Canadian Marconi Company's Beam receiving station at Yamachiche, near Montreal, which in turn passed it on to the broadcasting stations.

The wavelength employed on the Multiplex Beam link across the Atlantic was 16·575 metres.

Reports from Canada state that this was undoubtedly the finest broadcast of the Armistice Service ever heard there. In the afternoon of November 11th the Canadian Marconi Company telegraphed to London :—

> " Have received already hundreds of messages of congratulation from all over Canada and portions of the United States."

The arrangements for this Imperial broadcast were similar to those made on Sunday, July 7th, for the relay of the Thanksgiving Service in Westminster Abbey, which was broadcast throughout Canada by means of the Marconi-Mathieu Multiplex system at Bodmin, and reported by listeners in all parts of the Dominion to be heard as clearly as a first-class local broadcast.

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No. 15

THE MARCONI REVIEW

December, 1929

CONTENTS

COMMERCIAL SHORT WAVE WIRELESS COMMUNICATIONS. PART III.—FOREIGN SHORT WAVE SERVICES - - - - - - - - PAGE 1

THE CALIBRATION AND CORRECTION OF NAVAL DIRECTION FINDERS - - - - - - „ 18

WIRELESS TELEPHONY AND DIRECTION FINDING IN THE FAR SOUTH. PART I. - - - - „ 22

OBITUARY NOTICE - - - - - - - „ 26

THE FIRST TRANSATLANTIC WIRELESS SIGNAL - „ 27

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD.

Marconi House, Strand, London, W.C. 2

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THE MARCONI REVIEW

No. 15. *December, 1929.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

COMMERCIAL SHORT WAVE WIRELESS COMMUNICATIONS

PART III.—FOREIGN SHORT WAVE SERVICES*

In the first two parts of this article, which appeared in THE MARCONI REVIEW, *Nos.* 13 *and* 14, *the Empiradio and Via Marconi beam services were dealt with.*

In this last part, the foreign short wave services, which have their centres in New York, Paris, and Berlin are described, as without this addition, the full scope of operation of the British services which are interconnected with them, cannot be completely understood.

TO complete this review of the present position of commercial short wave communications, some details will now be given of the traffic organisations and equipment at the other great centres of the International wireless network.

The United States Commercial Short Wave Services.

In magnitude and importance, the commercial wireless services of the United States hold a leading place.

By far the greater number come under the control of the Radio Corporation of America, to whom I am indebted for much of the following information. The R.C.A. send out traffic on about 42 circuits and chiefly with Short Wave transmitters. The dates when these services were established are given in the table below :—

British	Between New York and				London ...	...	March 1st, 1920.
Norwegian, L.W.	,,	,,	,,	,,	Oslo ...	...	May 17th, 1920.
German	,,	,,	,,	,,	Berlin ...	...	August 1st, 1920.
French	,,	,,	,,	,,	Paris ...	...	December 14th, 1920.
Italian	,,	,,	,,	,,	Rome ...	...	August 10th, 1923.
Polish, L.W. ...	,,	,,	,,	,,	Warsaw ...	...	October 5th, 1923.
Swedish, L.W. ...	,,	,,	,,	,,	Gothenburg	...	December 1st, 1923.
Argentine ...	,,	,,	,,	,,	Buenos Aires	...	January 22nd, 1924.
Brazilian	,,	,,	,,	,,	Rio de Janeiro	...	May 3rd, 1926.
Holland	,,	,,	,,	,,	Amsterdam	...	November 1st, 1926.
Dutch West Indies	,,	,,	,,	,,	Curaçao ...	...	June 21st, 1927.
Dutch Guiana ...	,,	,,	,,	,,	Paramaribo	...	August 9th, 1927.
Venezuelan, L.W.	,,	,,	,,	,,	Caracas ...	...	August 18th, 1927.
Colombian ...	,,	,,	,,	,,	Bogota ...	...	August 27th, 1927.
Belgian, L.W. ...	,,	,,	,,	,,	Brussels ...	...	October, 3rd 1927.
Porto Rican ...	,,	,,	,,	,,	San Juan	...	October 10th, 1927.
Turkish, L.W. ...	,,	,,	,,	,,	Angora ...	...	December 10th, 1927.
Venezuelan, No. 2	,,	,,	,,	,,	Maracaibo	...	January 22nd, 1928.
Canadian	,,	,,	,,	,,	Montreal	...	March 10th, 1928.
Portuguese ...	,,	,,	,,	,,	Lisbon ...	...	April 2nd, 1928.

* The following is a reprint of a lecture delivered by H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E., before the Radio Society of Great Britain, at the Institute of Electrical Engineers, on September 27th, 1929.

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Siberian	Between New York and	Monrovia ...	September 1st, 1928.
Cuban	,, ,, ,, ,,	Havana	December 4th, 1928.
Chilean	,, ,, ,, ,,	Santiago ... (operated via Buenos Aires)	... January 1st, 1929.
	,, ,, ,, ,,	San Jose, Costa Rica	September 3rd, 1927.
Spanish	,, ,, ,, ,,	Madrid	August 1st, 1929.
	,, San Francisco and	Suva ...	April 22nd, 1929.
	,, San Juan and	San Domingo ...	May 15th, 1929.
Hawaiian ...	,, San Francisco and	Honolulu ...	March 1st, 1920.
Japanese	,, ,, ,, ,,	Tokio ...	March 1st, 1920.
Dutch East Indies	,, ,, ,, ,,	Malabar ...	July 16th, 1925.
French Indo-China	,, ,, ,, ,,	Saigon ...	September 15th, 1926.
Philippines ...	,, ,, ,, ,,	Manila ...	June 27th, 1927.
Hong Kong ...	,, ,, ,, ,,	Hong Kong (operated via Manila)	October 18th, 1927.
Chinese	,, ,, ,, ,,	Shanghai (operated via Manila)	... February 21st, 1928.
	2/10/29 Discontinued working with French station, continued with Chinese Government station.		
	Between Manilla and	Osaka	October 30th, 1927.
	,, ,, ,,	Java-Bandoeng ...	October 17th, 1927.
	,, ,, ,,	Bangkok	
	,, ,, ,,	Saigon	November 1st, 1927.
	,, ,, ,,	Berlin	August 16th, 1927.
	,, ,, ,,	Buenos Aires ...	February 11th, 1929.

Other American Services.

The Tropical Radio Telegraph Co., works Central America with about seven circuits all on Short Wave.

The Mackay Radio & Telegraph Co. provides a wireless service to Hawaii on Short Wave and some overland Long and Short Wave circuits on the Pacific Coast.

There is also the transatlantic wireless telephone service from the American Telegraph & Telephone Co. at New York to the British Post Office at London, which employs two Short Wave sets and five wavelengths in addition to the Long Wave channel.

The R.C.A. Broadside Projector Antenna.

Following the example set by Great Britain in the use of aerials which transmit beam radiation, the principal short wave commercial stations of the United States, France and Germany, have now had installed aerials which have a similar object in view, called "projector antennæ," as their employment has become a necessity to meet the requirements of high speed traffic over as long a period as possible of the 24 hours, which compels the use of a strong signal.

Thus for many of their short wave services, the Radio Corporation of America employ the R.C.A. Broadside Projector antenna, which is illustrated in Fig. 26. This is a view of the 4 bay 16·8 m. aerial installed at Radio Central, Rocky Point.

It consists of two rows of equally spaced vertical radiators extending in parallel lines for a distance varying from 3 to 12 wavelengths, depending on the desired degree of directivity. Each row is energised from a common central horizontal feeder bus, the bus in turn being energised by a transmission line.

The two parallel rows of poles, cables and reflector elements represent the antenna proper, and its reflectors spaced 5 quarter wavelengths apart. These poles are of wood, and only $1\frac{1}{8}$th wavelength high.

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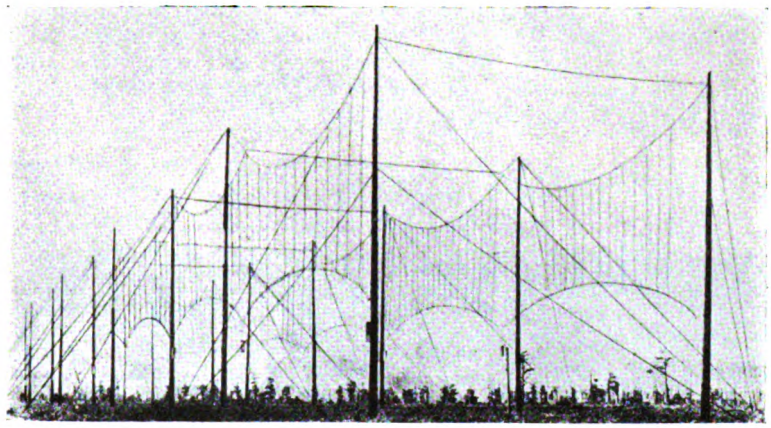

FIG. 26.

The feeder bus, which is too faint to be seen in the illustration, runs horizontally half way up the aerial array, and is bridged by a tuning coil at each vertical radiator.

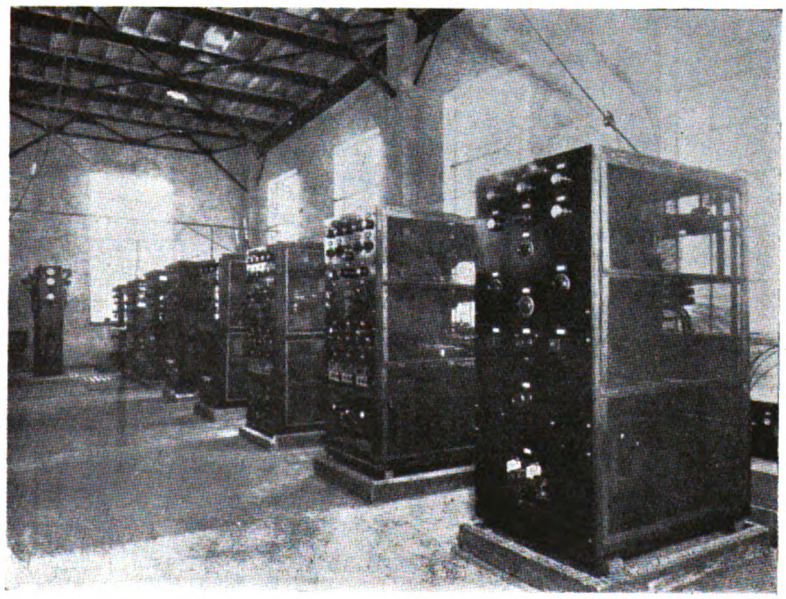

FIG. 27.

The radiators are so disposed that they form in effect, a half-wave aerial with a tuning-coil at the centre of each.

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The radiators are arranged to produce electrical and mechanical symmetry with respect to the central feeder bus. The transmission lines may be several thousand feet in length to allow the aerial to be erected free of all obstructions, and phasing adjustments for the transmission lines are accomplished by a local tuning system in a coil-house located at the centre of each bay of the aerial.

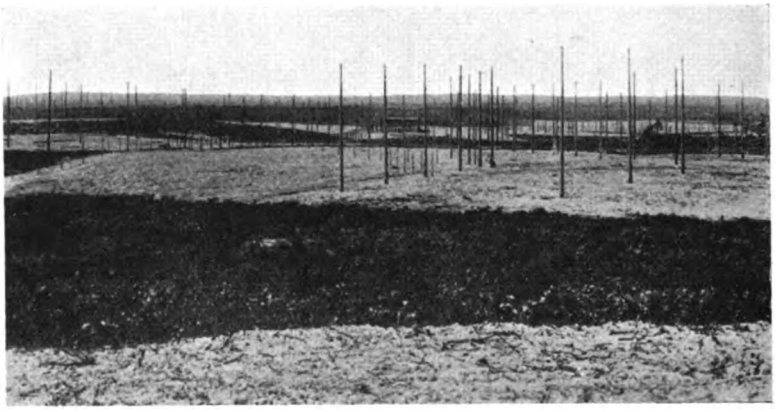

FIG. 28.

R.C.A. Short Wave Transmitters.

Four of the short wave transmitters at Radio Central are shown in Fig. 27. Each of them has two panels, the first containing the crystal controlled master oscillator, and the intermediate amplifier stages, and the second panel the power amplifier stage. The 10,000 volt rectifier valve panels are in another part of the building.

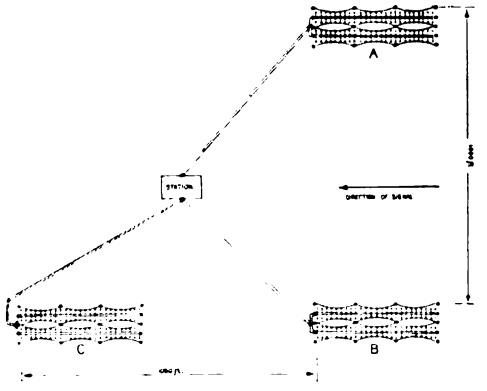

FIG. 29.

The R.C.A. Diversity System.

The short wave aerials at Riverhead, the Receiving Centre, cover a ground space of about one square mile. The illustration, Fig. 28, shows the short wave receiver building in the centre, and the five towers of a Marconi-Franklin Beam aerial, too faint to be seen, are in the background.

The special method of reception devised by the R.C.A. for commercial short wave working is called by them the Diversity system.

It aims at reducing to a minimum :—

(1) Interference caused either by natural disturbances or by signals on approximately the same frequency as the station to be received.

(2) Mutilation of the incoming signals caused by fading.

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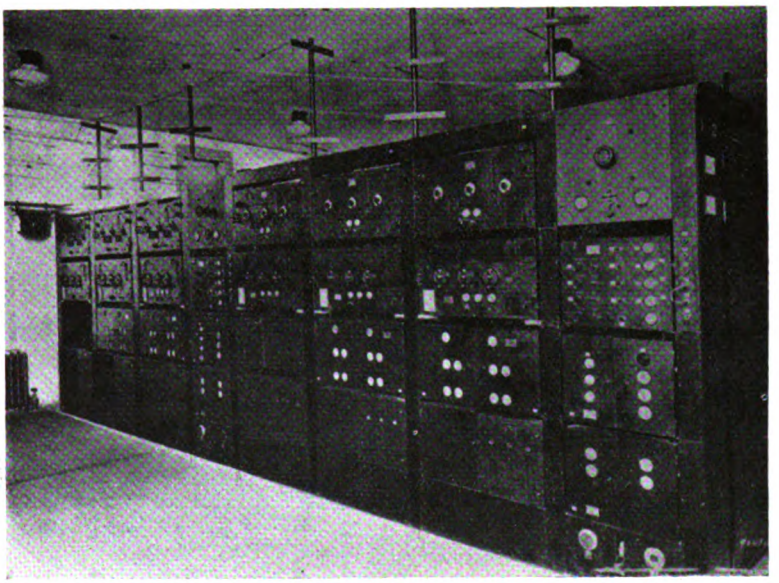
Three directional aerials are employed, spaced approximately 1,000 ft. apart, and full advantage is taken of the directional characteristic of each of them to reduce interference from either side and from the rear to a low value. Also, as it has now been proved that there is a difference in the time at which fading occurs on two aerials spaced only a few hundred feet apart, full use is made of this fact to reduce mutilation of signals due to deep fading by using three such spaced aerials to pick up the incoming signals.

A diagram of the arrangement employed is shown in Fig. 29. There are actually six aerial elements involved, the element being the short wave " Wave Antenna " developed by the R.C.A.



This consists of a number of horizontal doublets capacitatively coupled to a two wire transmission line. It is claimed that the horizontal system is superior to the vertical in signal noise ratio, on the assumption that local disturbances are vertically polarised, whereas distant signals are mostly horizontally polarised.

The principal on which this aerial works gives it directional characteristics similar to the Beverage Wave Antenna used for transoceanic reception on Long Waves.

Briefly, signals coming from the desired direction build up a voltage as they travel along the line of doublets, and the resulting current is fed into the receiving equipment, while signals from the opposite direction are dissipated in the terminating resistance.

The aerial is supported at a height of about 50 ft. by triatics broken by insulators. Space for a single unit aerial is 50 feet by 312 ft. Considerable improvement in directivity and voltage pick up is obtained by using two such aerial units in broadside. The Double or Broadside Antenna requires a space 100 ft. by 312 ft.

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Where several stations on approximately the same great circle are to be received simultaneously, only one of these aerial arrangements is needed. A number of Diversity Receivers may be operated from each Diversity Aerial, and due to the fact that the aerial characteristics are not obtained by sharply resonant elements or circuits, the entire present band of frequencies utilized for transoceanic communication on short waves may be covered, with about equal response by a single aerial array. This makes possible reception of both day and night waves and reception from a number of stations with but one aerial system.

FIG. 30.

A carefully balanced 4 wire transmission system is employed to connect the aerial to the receiving equipment so as to prevent the characteristics of the aerial itself from becoming impaired by energy picked up on the transmission lines. The four wires are kept in exact spacing and symmetry by special fixtures mounted on poles 10 or 12 ft. high, set 25 ft. apart.

The aerial arrangement then consists of two short wave "Wave Antennæ" combined to form one Broadside antenna, and three of these Broadside antennæ combined at the output of their respective receivers to form one Diversity receiving system.

The combined output signal is made to control the output from a local source of audio-frequency energy.

This final signal, which is constant in frequency and strength, is sent to Central Traffic Office over the usual landline, and works the automatic recording equipment used for high speed reception, which is capable of being operated at telegraph speeds up to 300 words per minute.

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Riverhead Receiving Equipment.

There are at the present time at Riverhead, 48 separate short wave wave antennæ forming 8 diversity antennæ groups, and it is intended to erect a total of 68 Diversity groups.

A rack housing two Diversity receivers in one of the bays of the short wave receiving building is shown in Fig. 29.

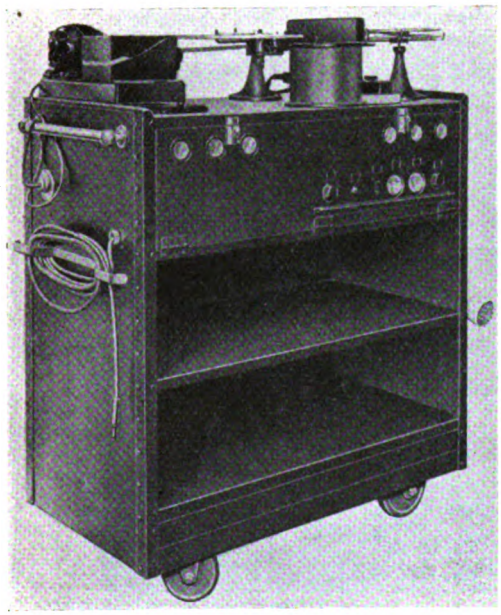

FIG. 31.

The Diversity Receiver to the right of the photograph for instance shows three similar metal screened boxes along the top, which are the radio frequency amplifiers of the three receivers corresponding to the three Broadside aerials, and below them are three other similar boxes. These are the three tuners.

The rest of the apparatus consists of three audio amplifiers, one master control unit, two converter units, one tone keyer, and one audio oscillator.

These receivers deliver audio signals to balanced potentiometers located on the control unit, which control the intensity of the audio frequency applied to the three separate converters.

The converters amplify and rectify their separate signals, and the three rectified currents then pass through separate meters on the control panel, after which the three rectified currents are combined. The combined rectified currents pass to the tone keyer where they key an audio frequency supplied by a local oscillator. This audio frequency tone passed to the landline leading to the recording apparatus in the Central Office.

The line control board at the end of the receiver room where the tone signals are plugged through to New York, is shown in Fig. 30, and the portable monitoring equipment, which becomes a necessity where there are so many receivers in Fig. 31. This consists of a combination amplifier and push-pull valve relay output for operating the recorder signal coil with reverse current.

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The Société Radio France Services.

The information kindly furnished me by the Société Radio France of the organisation of French Short Wave Commercial communications, is as follows :—

The State works the Colonial services which are at present carried on by two transmitting stations, built by the French Government, and installed at Lyons (La Doua) and by an auxiliary low power station installed at Bordeaux (Lafayette).

The two Lyons transmitters are of the self-oscillator type, employing a 15 kw. water-cooled valve. Several waves lying between 15 and 40 m. are used, according to the time of day, and the corresponding stations. The call signals are FYR and FYQ. The principal corresponding stations are Saigon, Hanoi, Tananarivo, Bammako and Djibouti.

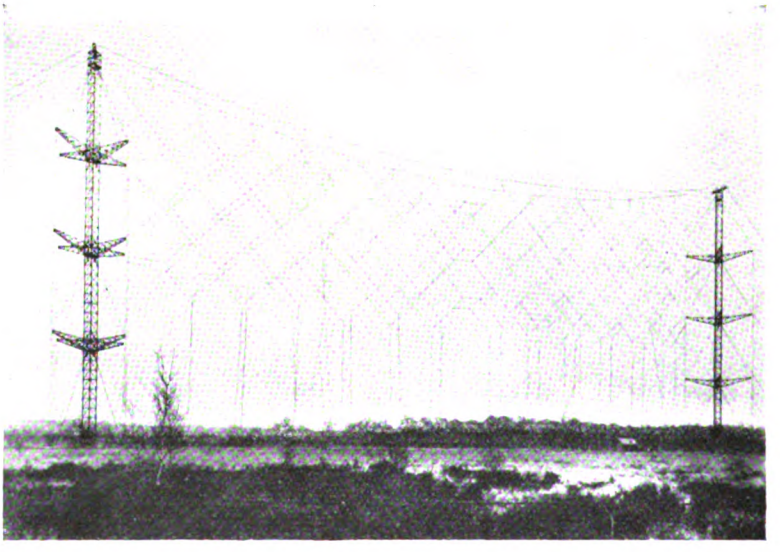

FIG. 32.

The Government has furthermore under construction at Pontoise (30 km. from Paris) a centre of short wave stations, which will start working at the end of 1929. This centre will be equipped at the outset by :—

> Two S.F.R. self-oscillator transmitters employing two valves of the 15 kw. type, and one S.F.R. transmitter, with quartz master oscillator and two valves of the 15 kw. type.

The corresponding receiving centre is under construction at Noiseux (25 km. from Paris).

The services from France to all other parts of the world, other than those enumerated above, are worked by the Cie. Radio-France, which employs the apparatus of the Société Francaise Radioelectrique.

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The transmitters of the Cie. Radio-France are grouped at Sainte-Assize (40 km. from Paris), and the receivers at Villecresnes (25 km. from Paris).

They at present comprise :—

(A) Two S.F.R. Self oscillator transmitters with two 15 kw. valves, which will be referred to later.

(B) One Marconi standard beam type transmitter.

(C) Three S.F.R. transmitters, each with quartz master oscillator and two valves of the 15 kw. type.

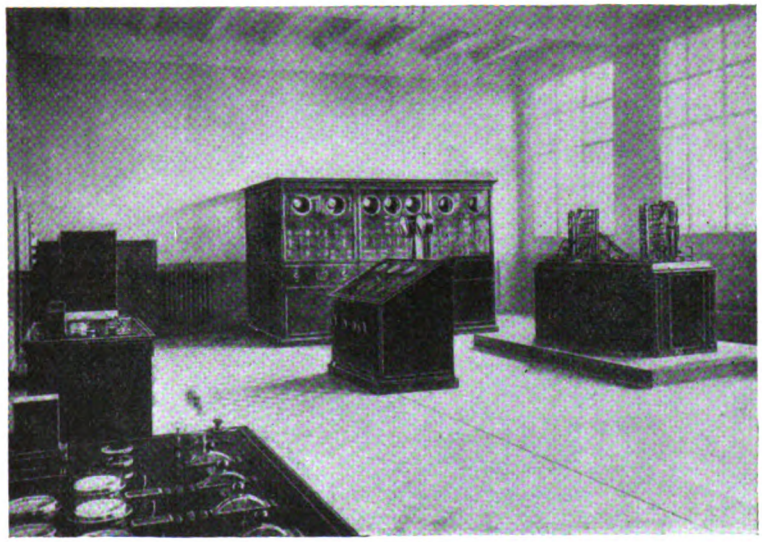

FIG. 33.

The services effected by these various transmitters are as follows :—

Type of Transmitter.	Call Signal.	Waves.	Corresponding Stations.
S.F.R. No. 1 self-oscillator transmitter...	FRO	15.45	Buenos Aires and Rio.
S.F.R. No. 1 self-oscillator transmitter...	FTL	30.10	Beyrouth—Vienna Belgrade.
S.F.R. No. 2 self-oscillator transmitter...	FFE	22.30	Beyrouth—Vienna Belgrade.
S.F.R. No. 2 self-oscillator transmitter...	FTD	15.10	New York.
Marconi Beam type transmitter ...	FQE	24.67	China—Japan.
S.F.R. No. 1 transmitter with quartz oscillator	FTM	15.50	Telephony Buenos Aires and telegraphy Bangkok.
S.R.F. No. 2 transmitter with quartz oscillator	FWR	24.50	Various telephony tests.
S.F.R. No. 3 transmitter with quartz oscillator	being	installed.	

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The S.F.R. C.M. Type Projector Aerial.

The particular form of projector aerial developed by the French is known as the S.F.R. C.M. type, and is illustrated in Fig. 32.

This shows a pair of masts supporting in the bay between them, two similar lozenge shaped networks, the transmitting aerial and its reflector, one behind the other. For a concentrated beam, an aerial occupying two bays would be used. The appearance of the receiving aerial is similar, but two sets of networks, one of small mesh for the day wave, and the other of large mesh for the night wave would be accommodated one above the other in a single bay.

The aerial and its reflector are constructed in a similar manner, but while the first is energised, the second is not.

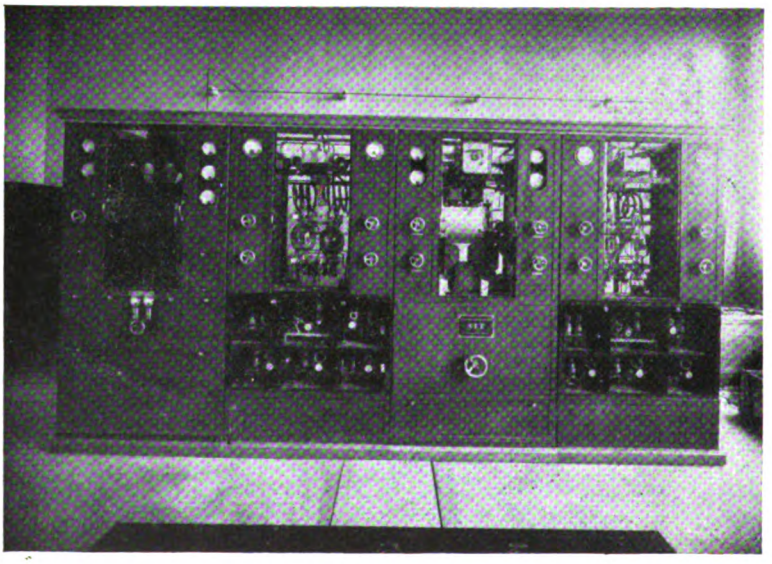

FIG. 34.

The principle of the construction of the aerial is that of a number of horizontal zig-zags connected together by insulators. The elements of wire in each zig-zag are half a wavelength long, and the currents therefore in all those elements inclined in the same direction are in phase.

The sum total of this construction, and the effect, is to produce two fields of radiation which cross each other at right angles, both of which give maximum effect in a horizontal direction.

A single pair of feeders at the centre of the aerial, or two pairs equally spaced are the usual practice, and the current distribution through the aerial is therefore not uniform.

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S.F.R. Short Wave Transmitters.

One of the S.F.R. S.W. transmitters at Ste. Assize is shown in Fig. 33. It can be seen on the right of the photograph. It consists of two water-cooled valve self oscillators. One of the oscillators may be used for the day wave, and the other for the night wave, or the two may be combined together to form one oscillator.

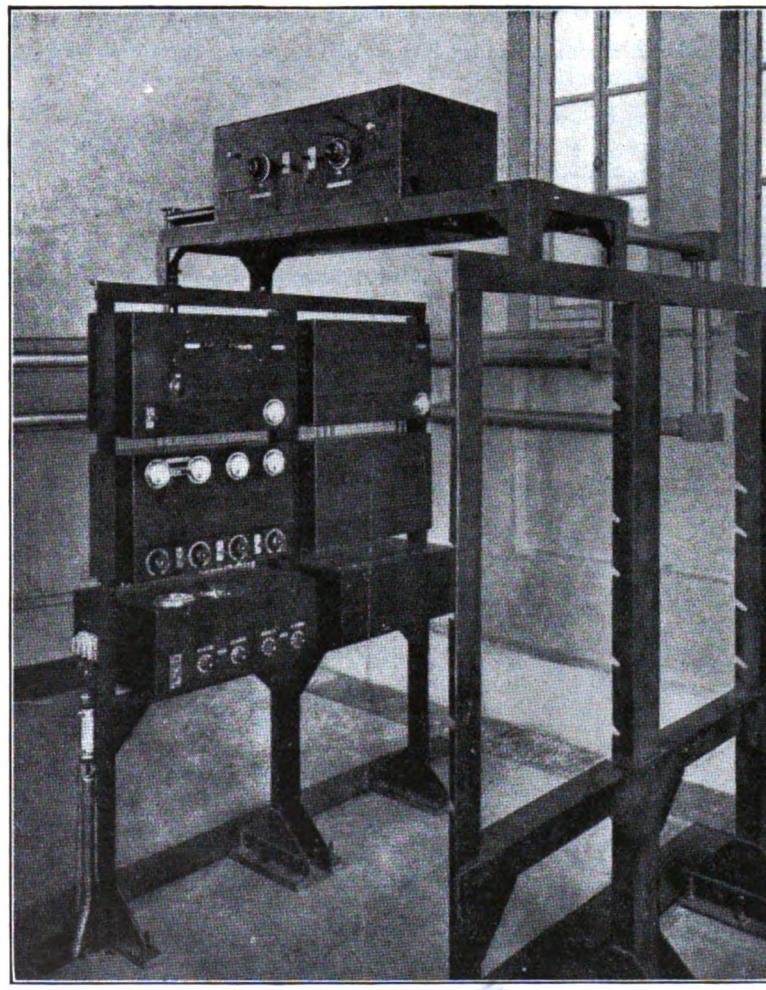

FIG. 35.

Its waverange is 12 to 50 m., and it is designed to work up to 150 words per minute. The three phase rectifier panel is against the wall, the control apparatus is in the centre of the photograph and the keying apparatus is on the left.

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The second type of S.F.R. S.W. transmitter installed at Ste. Assize is shown in Fig. 34. This is crystal controlled with guaranteed constancy of wavelength of a high order ; it delivers 15 kw. to the aerial, and like the uncontrolled type, is also a two-wave oscillator suitable for day and night working.

The S.F.R. Commercial Short Wave Receiver.

The long distance short wave receiver of the S.F.R. is illustrated in Fig. 35. This shows a rack for two receivers, only one being fitted.

On the top is an aerial coupling box, and the photograph also shows the concentric tube feeder connection to it.

Of the six boxes below, the top one to the left, No. 1, contains (A) a tuned amplifier, adjustable over a range of 12 to 50 m. ; (B) a frequency changer modulating the signal down to 750 kilocycles.

The box to the right, No. 2, contains (A) a two stage band amplifier ; (B) a second frequency changer which reduces the signal frequency to 25 kilocycles.

Box No. 3 contains a two stage band amplifier and a detector.

Box No. 4 a D.C. three stage amplifier, and an anti-fading regulator.

Box No. 5 the switchboard for distributing and adjusting the power feed voltages, while the different polarising batteries are contained in box No. 6.

A special modulating device is incorporated in box No. 1, which allows the operator to plug in his 'phones and listen-in to the signals.

The circuits are indicated in Fig. 36.

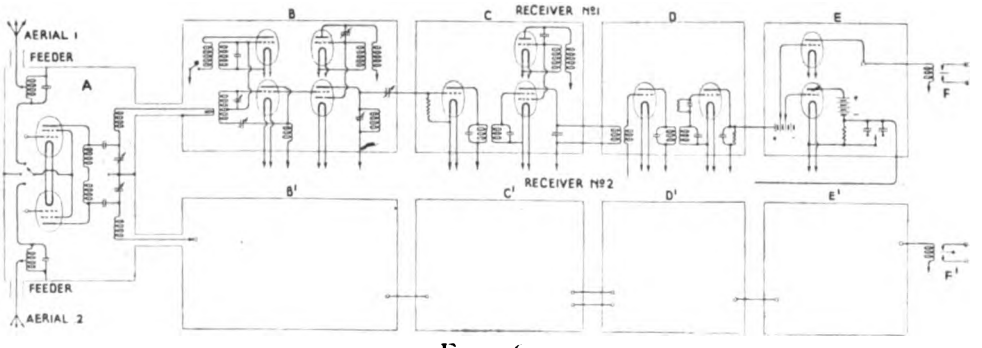

FIG. 36.

Transradio Services.

Through the courtesy of Transradio, Berlin, I am able to give you the following particulars of the German S.W. services, which reached me by air mail, from Berlin, a few days ago.

The inter-European wireless service is worked by the German Reichspost itself, and is at present confined to long waves, but the German overseas wireless services are worked by Transradio by virtue of a concession granted by the Reich in 1921 to operate for a period of 30 years.

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Besides the North America (New York) and Japan circuits which are at times still operated with long wave transmitters, the following purely short wave circuits are in operation :—

To Argentina	Opened in July, 1924.
,, Brazil	,, ,, August, 1926.
,, Chile	,, ,, April, 1929.
,, Egypt	,, ,, March, 1923.
,, China (Mukden)	,, ,, July, 1924, at first one-way to Mukden ; two-way connection from January, 1928.
,, Dutch Indies (Malabar) ..	,, ,, January, 1925.
,, Siam	,, ,, January, 1929.
,, Manila	,, ,, August, 1927.
,, Mexico	,, ,, August, 1929.

The Berlin—New York service was initiated in August, 1919. A one-way service to Japan was opened in November, 1926, and service both ways began in April, 1929.

The following short wave transmitters are in operation at present :—

BERLIN TO NORTH AMERICA.

Directional	DFA	15·592 m. day wave. 30·58 m. night wave.

BERLIN TO SOUTH AMERICA.

Directional	DFI	14·985 m. day wave. 30·364 m. night wave.
Directional	DGX	14·955 m.
Broadcast	DHA	27·701 m.
	DGI	22·429 m.

BERLIN TO EASTERN ASIA.

Directional	DGY	16·778 m.
	DHD	30·272 m.
	DHC	40·965 m.

TRANSOCEAN PRESS SERVICE.

Broadcast	DIH	15·040 m.
	DIS	29·557 m.

PROVISIONAL TRANSMITTERS.

Broadcast	DHC	26·224 m.
	DGW	14·896 m.

Telephony with Buenos Aires, which was opened in December, 1928, is at present carried on by means of DGW.

All the S.W. transmitters just mentioned are erected at the Nauen high power station.

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The long distance short wave receiver of the S.F.R. is illustrated in Fig. 35. This shows a rack for two receivers, only one being fitted.

On the top is an aerial coupling box, and the photograph also shows the concentric tube feeder connection to it.

Of the six boxes below, the top one to the left, No. 1, contains (A) a tuned amplifier, adjustable over a range of 12 to 50 m. ; (B) a frequency changer modulating the signal down to 750 kilocycles.

The box to the right, No. 2, contains (A) a two stage band amplifier ; (B) a second frequency changer which reduces the signal frequency to 25 kilocycles.

Box No. 3 contains a two stage band amplifier and a detector.

Box No. 4 a D.C. three stage amplifier, and an anti-fading regulator.

Box No. 5 the switchboard for distributing and adjusting the power feed voltages, while the different polarising batteries are contained in box No. 6.

A special modulating device is incorporated in box No. 1, which allows the operator to plug in his 'phones and listen-in to the signals.

The circuits are indicated in Fig. 36.

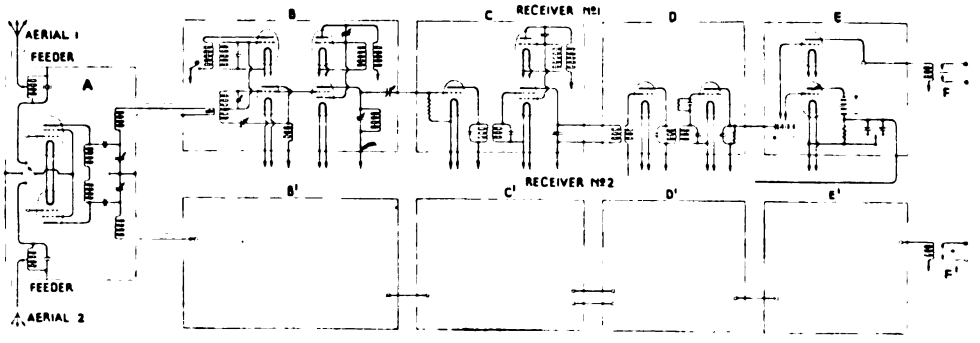

FIG. 36.

Transradio Services.

Through the courtesy of Transradio, Berlin, I am able to give you the following particulars of the German S.W. services, which reached me by air mail, from Berlin, a few days ago.

The inter-European wireless service is worked by the German Reichspost itself, and is at present confined to long waves, but the German overseas wireless services are worked by Transradio by virtue of a concession granted by the Reich in 1921 to operate for a period of 30 years.

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Besides the North America (New York) and Japan circuits which are at times still operated with long wave transmitters, the following purely short wave circuits are in operation :—

To Argentina	Opened in	July, 1924.
,, Brazil	,,	,, August, 1926.
,, Chile	,,	,, April, 1929.
,, Egypt	,,	,, March, 1923.
,, China (Mukden)	,,	,, July, 1924, at first one-way to Mukden; two-way connection from January, 1928.
,, Dutch Indies (Malabar) ..	,,	,, January, 1925.
,, Siam	,,	,, January, 1929.
,, Manila	,,	,, August, 1927.
,, Mexico	,,	,, August, 1929.

The Berlin—New York service was initiated in August, 1919. A one-way service to Japan was opened in November, 1926, and service both ways began in April, 1929.

The following short wave transmitters are in operation at present :—

BERLIN TO NORTH AMERICA.

Directional	DFA	15·592 m. day wave. 30·58 m. night wave.

BERLIN TO SOUTH AMERICA.

Directional	DFI	14·985 m. day wave. 30·364 m. night wave.
Directional	DGX	14·955 m.
Broadcast	DHA	27·701 m.
	DGI	22·429 m.

BERLIN TO EASTERN ASIA.

Directional	DGY	16·778 m.
	DHD	30·272 m.
	DHC	40·965 m.

TRANSOCEAN PRESS SERVICE.

Broadcast	DIH	15·040 m.
	DIS	29·557 m.

PROVISIONAL TRANSMITTERS.

Broadcast	DHC	26·224 m.
	DGW	14·896 m.

Telephony with Buenos Aires, which was opened in December, 1928, is at present carried on by means of DGW.

All the S.W. transmitters just mentioned are erected at the Nauen high power station.

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The telegraph traffic carried by the wireless services, enumerated above, has risen from year to year, as will be seen from the following table :—

	1919	..	..	1·2 million	words.
	1920	..	..	2·9 ,,	,,
	1921	..	..	5·0 ,,	,,
	1922	..	..	6·5 ,,	,,
	1923	..	..	7·7 ,,	,,
	1924	..	..	10·8 ,,	,,
	1925	..	..	11·9 ,,	,,
	1926	..	..	12·7 ,,	,,
	1927	..	..	13·4 ,,	,,
	1928	..	..	16·3 ,,	,,
In the first half-year	1929	..	..	8·6 ,,	,,

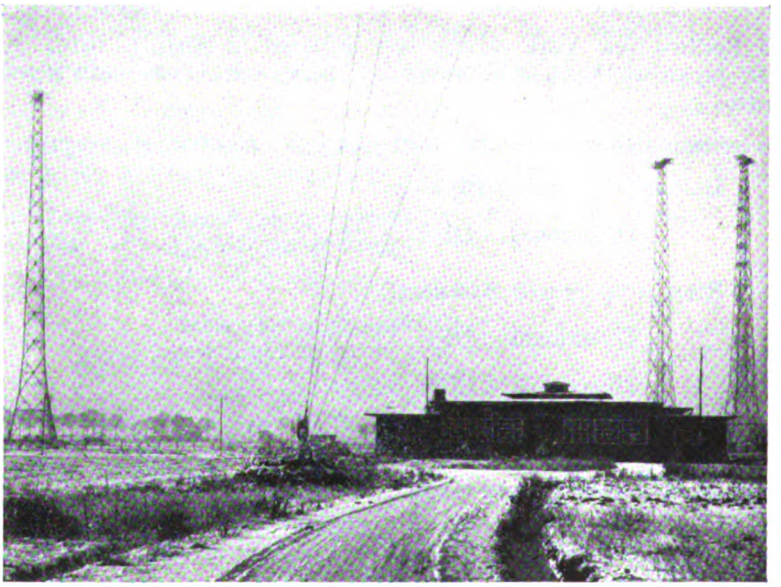

FIG. 37.

The receiving installations are at Geltow, near Potsdam. The building of a new short wave receiving installation equipped with the latest devices has been commenced near Beelitz, about 46 km. from Berlin. The telegraph operating service itself is carried out at the Transradio operating centre, Berlin, which is opposite the Central Telegraph Office, to which it is connected by a pneumatic post installation. There has been a similar working centre at Hamburg since the end of 1924 for dealing with the important Hamburg and North German over-sea traffic, and both working centres have special telegram transmitting offices, with private lines for special clients.

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The Transradio Projector Aerial.

The building housing the Short Wave transmitters at Nauen, is shown in Fig. 37, with two out of the three masts which support the two bays of aerials forming

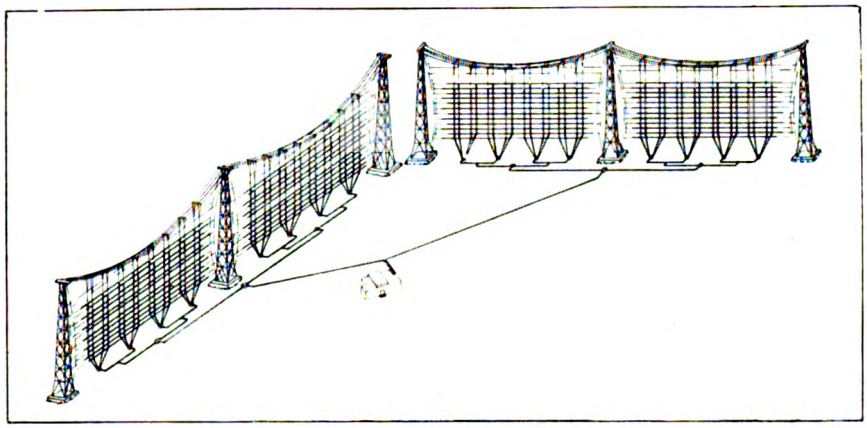

FIG. 38.

the Beam projector for the South American service. The mast to the right belongs to the projector used on the New York service.

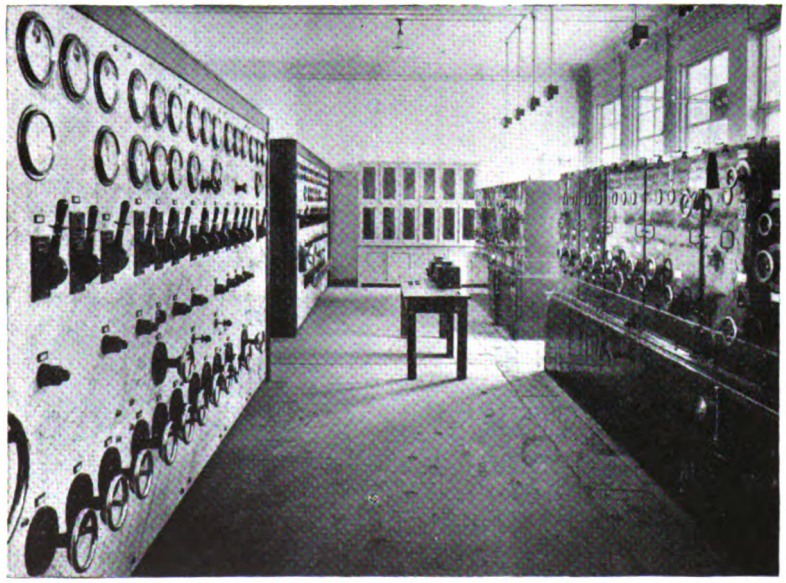

FIG. 39.

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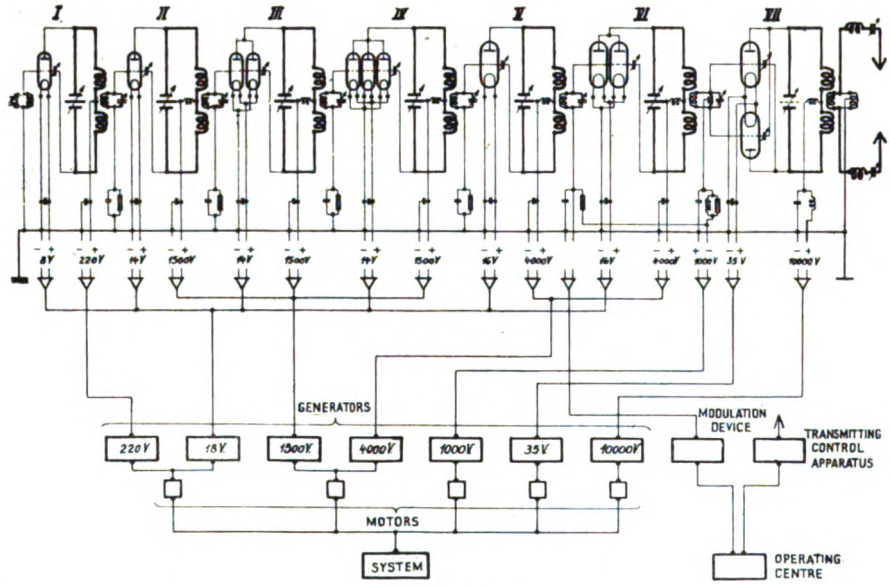

FIG. 40.

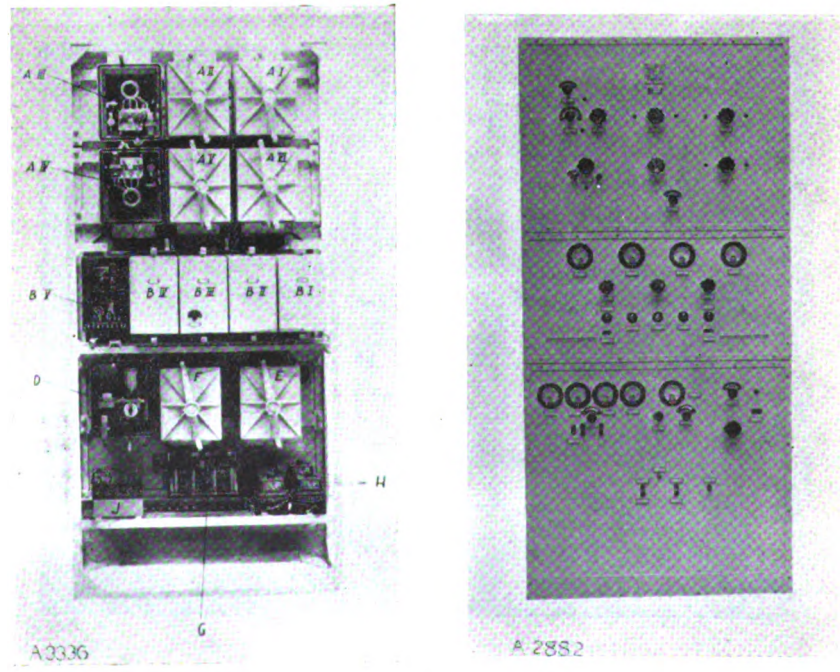

FIG. 41.

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A fairly clear idea of the German type of projector aerial can be obtained from Fig. 38. The two bays of wires between the three masts on the left form the projector for the South American service, while a similar projector for New York is on the right.

The arrangement consists of a vertical sheet of horizontal doublets backed by a similar sheet of wires which acts as a reflector.

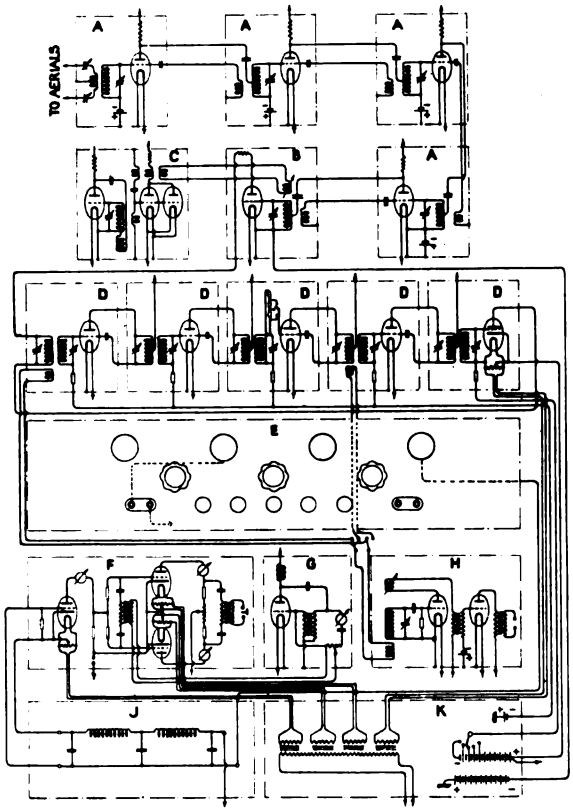

FIG. 42.

A	*H.F. Amplifiers*	*F.*	*Keying Apparatus*
B.	*Rectifier.*	*G.*	*Note Oscillator.*
C.	*Heterodyne.*	*H.*	*Listening Unit.*
D.	*I.F. Amplifiers.*	*J.*	*Sine Filter.*
E.	*Control Board.*	*K.*	*Transformer.*

Both the aerial and reflector wires are energised.

The feeders which originally coupled to the aerials right and left of the central mast, are here shown bifurcating to many feeding points in each bay, similar to the Marconi-Franklin feeder, but differing, however, in that both the feeder lines are insulated.

Transradio Transmitters.

Two of the seven-stage crystal controlled short wave transmitters used on the American service are shown on the right in Fig. 39, with their main switchboards on the left. A schematic diagram of the transmitter is given in Fig. 40.

A back and front view of the commercial short wave receiver is shown in Fig. 41, and it will be noted that the panel system is adhered to. Each stage has its own screening box with a special method for ensuring that the covers are locked tight in place.

This ends the account I have attempted to give you of the commercial short wave services of the World.

Incomplete as it is, it may yet have enabled you to visualise better the present magnitude and the great possibilities of these National and International services, the skill with which they are conducted, and the sound enterprise which relies on the guidance of advanced research for their development.

In conclusion, I have to express my thanks to the British Post Office, to the Radio Corporation of America, to the Cie. Radio France, to Transradio, and finally to Marconi's Wireless Telegraph Co., for much information and the many illustrations I have used in this paper.

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THE CALIBRATION AND CORRECTION OF NAVAL DIRECTION FINDERS

Practical experience in the control of ships by the use of wireless direction finders has shown that this method is just as efficient and reliable as any other system which can be used for the same purpose.

Any naval direction finder, however, suffers from certain inherent errors, just as does the mariners' compass, and these are discussed in the following article.

It is shown that the nature of these errors can be obtained theoretically and correction curves made which enable very accurate bearings to be obtained from such an instrument as the type D.F.M.4 direction finder to which the following article refers.

INSTALLATIONS of the D.E.M.4 type have recently been carried out in the Argentine Destroyers " Mendoza," " Tucuman " and " La Rioja."

The apparatus in question is of the standard type that has already been described in some detail in THE MARCONI REVIEW (see No. 8, May, 1929).

The design is such that great accuracy is possible so long as the installation is carefully calibrated and adjusted.

Without proper calibration, the best D.F. set is of no more value than an uncorrected magnetic compass, and, surprising as it may seem, nautical men have been somewhat slow to realise this. Happily this state of affairs is improving, and, by proper co-operation, it is now usually possible to compare a sufficiently large number of wireless test bearings with visual observations and gyro compass readings, to enable a reliable error curve to be drawn, so that the most appropriate corrections can be applied.

Good calibration results can be obtained either by using a low power transmitter fitted into a motor boat which can cruise round the ship at a suitable radius, or by swinging the ship and listening to a fixed transmitting station having a known direction. In many cases it is difficult to turn the ship sufficiently whilst under way, but sometimes the ship may be anchored in a tide-way and it is possible to take a series of bearings as the ship turns with the tide.

Precautions are of course necessary whatever method is used and much patience is required.

Nature of Errors due to Ship's Structure.

Having obtained as many bearings as circumstances permit, differences as between wireless dial readings and true bearings relative to the ship's head are plotted against dial reading.

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In general, this plotting gives an error curve which resembles two complete sine waves for one revolution of the search-coil. This resemblance only applies to ships producing small errors as we shall now see.

It is obviously important that we should have a good idea as to what shape of curve is to be expected, because we shall then be in a position not only to reject experimental errors, but also to deal intelligently with parts of the quadrants where it may have been impossible to obtain adequate checks. The metal work of a ship is a very complex structure from an electrical point of view, and, at first sight, it might appear impossible to forecast the nature of the errors caused by secondary fields set up by currents induced in the structure.

Fortunately, however, experience shows that the error is almost entirely of the type that could (in the absence of the ship) be produced by a single large closed conducting loop with its plane vertical and placed below the D.F coils. From the point of view of primary errors, the ship's structure can in fact be replaced by a closed loop whose plane is roughly in the fore-and-aft line and whose dimensions and proximity to the D.F. set are such that the same *amount* of error is introduced.

The current in this equivalent loop will clearly be zero for transmitting stations abeam and will have a maximum value for stations ahead and astern. In consequence there will be no secondary field and no error for stations abeam, and when taking bearings ahead or astern, there is also zero error because the search coil is then coupled only to the thwartship B-T loop through which the secondary field does not pass.

If the ship is electrically asymmetrical as viewed from the D.F. site, the effective or equivalent loop will not be exactly in the fore-and-aft line, and instead of having zero errors at dial readings of 0°, 90°, 180° and 270°, we shall have zero errors at four other readings, for example, 3°, 93°, 183° and 273°.

It has been shown (MESNÉ) on reasonable grounds that the relation between the real and apparent bearings in a ship is given by :—

$$\text{Tan}\,\phi = A\ \text{Tan}\,\theta$$

where ϕ = True bearing relative to ship's head.
θ = Apparent bearing relative to ship's head.
A = A constant depending on the ship's geometry and electrical conductivity and on the position of the D.F. loops.

From this expression, it is possible to derive error/dial reading curves of various maximum amplitudes (corresponding to various ships and D.F. positions).

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Such curves may be plotted on transparent paper for maximum errors up to say 20°, and, armed with a curve " family " of this kind, it is a simple matter to find out which curve best fits the results in any given ship.

A family of these curves is shown in Fig. 1.

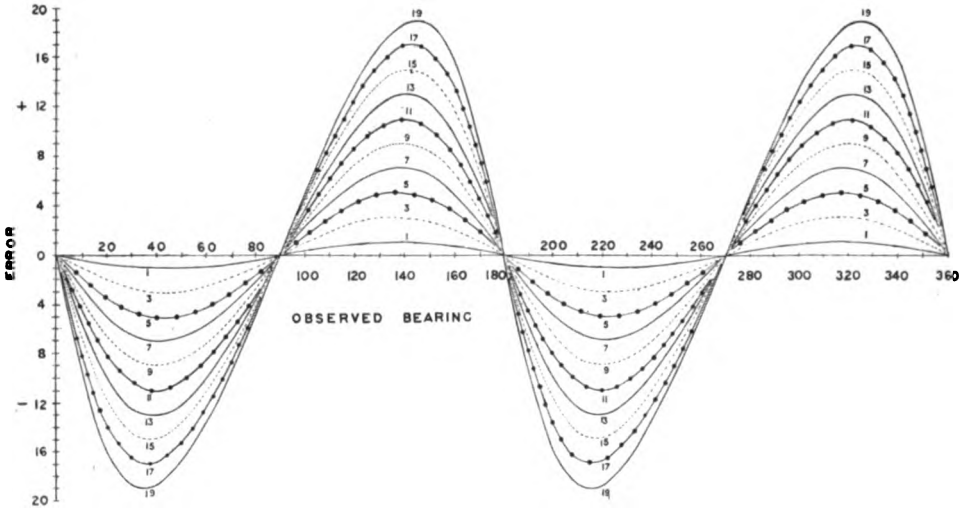

FIG. 1.

Correction of Errors.

The derived curves, to which we have referred, have been found to apply remarkably well in practice to the vast majority of ships, hence it is possible to eliminate the errors in all ordinary cases by a common correcting method.

The corrections introduced must of course obey the same law as do the errors to be eliminated.

The Marconi method of shunting one of the B.T. loops by means of a choke, does follow the tangent law already indicated, and one merely has to adjust the value of choke in order to control the *amount* of correction.

Reverting now to the actual process of calibration, it is usually best to take all test bearings with the choke disconnected. The errors are then plotted and it is easy to see what correction is necessary.

In selecting a curve from the "family" it has to be remembered that a bodily displacement along the horizontal axis (dial reading) may be justified by electrical asymmetry of the ship and that a bodily displacement vertically (error axis) may be caused by an error of pointer or search-coil alignment.

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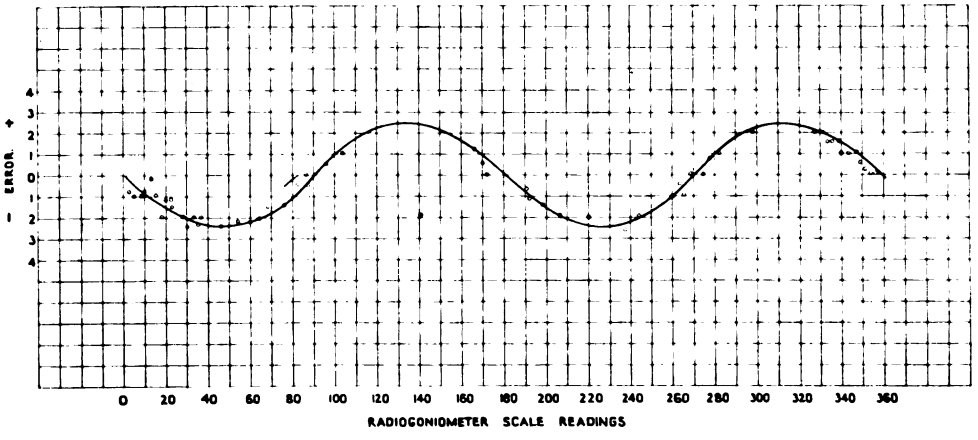
If, after choosing the best curve, the latter is seen to be displaced horizontally, the B.T. loops must be rotated as a whole through an angle equal to this displacement, otherwise even a correct adjustment of calibrating choke will not have the desired effect. It is not often that one has to readjust the orientation of the B.T. loops, but it is likely to be necessary if the loops are installed off the fore-and-aft line of the ship, and may be quite important in large ships where the amplitude of the error curve is great.



The D.F.M.4 installation in the Argentine Destroyer " La Rioja " was calibrated by taking bearings on the Daventry Broadcast stations as the ship turned with the tide.

The errors, prior to the application of the correcting choke are shown in Fig. 2.

It will be seen that the errors are entirely rational and, as might be expected, were eliminated quite accurately by using a suitable choke tap. Further checks on other stations indicated that the correction was not only accurate for the wavelengths used in calibration but also for all others within the range of the instrument.

NORMAN LEA.

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WIRELESS TELEPHONY AND DIRECTION FINDING IN THE FAR SOUTH

PART I.

The primary purpose of this article is to assist designers of the type of wireless installation used on Whaling Vessels, and to inform agents who are selling such apparatus as to the actual conditions under which the apparatus has to work.

To the general reader the article possesses special interest in that it is written by an engineer who has studied these conditions on the spot and who possesses first-hand information on the subject.

IN 1925 the Marconi Company turned their attention to the possibilities of wireless telephony among the Whaling Fleets in the Antarctic, and in order to obtain first-hand knowledge, an Engineer was despatched to South Georgia with instructions to study the Whaling Industry. As a result of experiments carried out in these regions, the Marconi Company designed a series of foolproof wireless telephone sets suitable for installation on Whale Catchers and Trawlers.

The first of these transmitters was the now well known X.M.C. 1 "Whaler" Telephone Set, which had a power of between 100 and 150 watts to the aerial and was designed in such a manner that it was as simple to operate as the ordinary office telephone.

Immediately this transmitter was placed on the market orders were received from the principal British and Norwegian Whaling Companies to equip their Whaling Fleets with this type of installation, and in addition the Southern Whaling & Sealing Company ordered a Wireless Telephone Land Station to be installed at their Whaling Base at South Georgia.

During the summer and autumn of 1926, the Land Station at South Georgia was erected, and many British and Norwegian Whalers fitted with the type X.M.C. 1 "Whaler" Telephone Set. The reliability of these sets can be judged by the fact that although they have been in constant use without skilled attention of any kind, and subject to the most adverse weather conditions for three and a half years, not a single breakdown of any importance has been reported, and according to the

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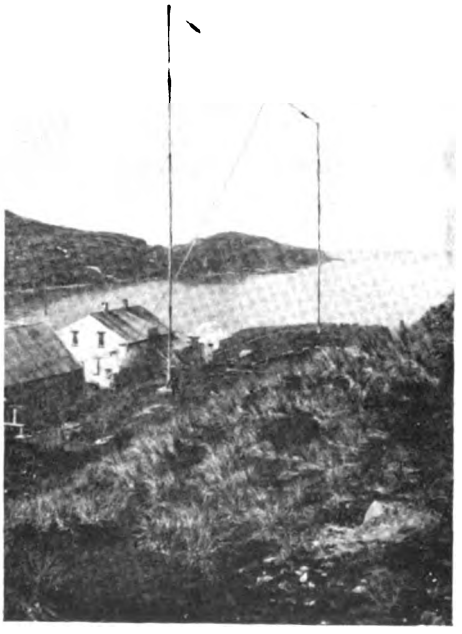
latest information the original transmitting valves are still in use on all the installations. This is indeed a wonderful achievement considering that these installations are operated by the crew of the whale catchers, who have absolutely no knowledge of the principles of wireless telephony.

Owing to the success of the X.M.C. 1 Telephone Sets, the Marconi Company developed two sets of lower power, for installation on Whalers and Trawlers which required to communicate only over distances of approximately 125 miles and under. These sets—with the exception of the power and size of the transmitter—are identical with the X.M.C. " Whaler " Sets and are just as simple and reliable in operation. The X.M.D.1 has an aerial power of between 50 to 60 watts, and the X.M.B.1 an aerial power of between 30 and 35 watts.



Marconi Wireless Land Station at Prince Olaf Harbour, South Georgia.

To understand the use to which these Telephone Sets are put, it is essential that the reader should have some idea of the organisation of the Whaling Fleets.

Whaling Fleets of the present day are divided into two categories :—

(i) A Fleet which works in conjunction with a land base ; and

(ii) A Fleet which works in conjunction with a floating base.

Fleets Attached to Land Base.

The Whaling Station, which comprises all the machinery, boilers, etc., for extracting the oil from the carcases of the whale, is situated on a suitable island, the majority of the stations at present being centred at South Georgia in the South Atlantic.

From each Land Base operate four or five steam whale-catchers (British and Norwegian regulations allow a maximum of five boats per station), each catcher being about the size of a trawler and carrying a crew of from nine to twelve men. All the stores, bunkers, ammunition, etc., for these whaleboats are kept at the Land Base and only sufficient supplies are placed on board the catcher for immediate

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requirements. The whale-catchers hunt the seas within a radius of 100 miles from the Land Base and rarely exceed this distance owing to the fact that every whale

Two Whale Catchers in the Ross Sea.

they shoot they must themselves tow back to the Base, as the regulations do not permit the use of a vessel solely for the purpose of towing the whales to the base.

Before the introduction of wireless telephony into the whaling industry, it was the practice for the catchers to act as individual units with the result that the location of a productive whaling area was generally a matter of luck. Wireless telephony has revolutionised this important part of the industry as it is now possible for all units of the fleet to co-operate together and work as a team. The practice now is for the catchers to leave their base just before dawn and proceed in different directions in search of whales. Immediately one of the catchers sight a school of whales, communication is established with the other boats by means of wireless telephony and the position of the school given to the gunners so that they can converge on this area and obtain a good catch, instead of wasting their time searching in unproductive areas. When wireless telephony was first introduced into the Whaling Fleets, it was found rather difficult to get the gunners to work together as a team, but it did not take them very long to see that this was the only way to increase their catch, and to-day the gunners keep in hourly telephonic communication with each other, with the result that the whale catch during recent years has broken all records. The Directors of the Whaling Companies very quickly appreciated the advantages of their gunners working together as a team, and to encourage this they gave to each member of the whale-catcher's crew a bonus on the total production of the station, in addition to the individual bonus allotted to each vessel for every whale they

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caught. This procedure encourages every gunner to inform the other gunners attached to his fleet when he has located a productive area, as by doing so he enables his colleagues to also obtain a good catch, and thereby increases the production of the station to which they are attached, thus increasing his own share of the bonus.

The whalers now consider that wireless is so essential to their trade that they will not sail without it, with the result that every whaling company of any importance has equipped its fleets with wireless telephone apparatus.

As is well known, wireless communication can be effected either by telegraphy, for which the Morse Code is used, or by telephony. Each of these methods has its own particular advantages and therefore its own field of application.

For communicating between the various units of a Whaling or Fishing Fleet, telephony has a decided advantage over telegraphy. The use of telegraphy necessitates the employment of a specially trained operator, and apart from the expense entailed on this account, it means that the ability of the vessel to communicate is dependent on one man, who might conceivably be incapacitated by sickness or accident. Wireless Telephony, however, overcomes this difficulty, since skilled operators are not required and direct conversation can be carried on by any member of the crew.

A wireless telegraph transmitter has approximately twice the range of a telephone transmitter of the same power, and for this reason it has been suggested that in spite of the disadvantages quoted above, wireless telegraphy should be fitted, as the greater range obtainable would enable the whale-catchers to operate hundreds of miles from their base and still keep in communication with their headquarters. Our experience has been that whale-catchers do not, and in fact cannot, efficiently operate hundreds of miles from their base. The radius of operation of the catchers is restricted to about 100 miles, due to the fact that every boat must tow in its own catch of whales, and even the most powerful whaleboat with four or five whales alongside cannot steam more than about five to six knots, with the result that if she were to operate say 500 miles from her land base, it would take her between three and a half to four days to tow her catch back to the factory. During this long tow the whale would decompose and the gases generated would result in the carcass being inflated to such a size that it would be very unwieldy to handle, and at the same time this decomposition would result in a great deal of valuable oil being lost.

In order to meet all conditions of service, the Marconi " Whaler " Telephone Sets have been designed to work also as continuous wave and interrupted continuous wave telegraph transmitters and keying units are provided for this purpose.

Fleets Attached to Floating Factories.

All the conditions stated above apply to whale-catchers which operate from a floating factory. The floating factory is a large ship, generally of the tanker class,

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upon which is fitted all the machinery, boilers, etc., necessary for extracting the oil from the carcass of the whale. Four or five steam whale-catchers are attached to each factory ship and operate within a radius of 150 miles from this base.

From the above remarks it is easy to understand that what the whaler requires is a simple telephone set, capable of giving a perfectly reliable telephone service with the base and with the other vessels of the fleet up to a distance of approximately 150 miles. This range can always be obtained by a standard X.M.C. " Whaler " Set.

On the rare occasions when a whaleboat may proceed up to say 250 miles from her base in search of new fishing grounds, the X.M.C. type of telephone set is still capable of maintaining telephonic communication with the base, with the result that information can be conveyed to the Whaling Manager regarding productive fishing areas, and the factory ship can steam with her catchers to the required spot.

Reports show that under favourable atmospheric conditions, and over sea, good communication can often be maintained between whale-catchers at distances exceeding 500 miles, and even when atmospheric conditions are not too favourable, communication can generally be relied upon over distances of 150 to 200 miles.

Having satisfactorily solved the problem of inter-ship communication on the fishing grounds, the Marconi Company have now looked into the question of providing means of communication between the whale-catchers and shipping during the voyage out from Europe to the Antarctic.

(*To be continued.*)

ADMIRAL SIR HENRY JACKSON

We very much regret to have to announce the death, on December 14th, 1929, of Admiral Sir Henry Bradwardine Jackson, G.C.B., K.C.V.O., F.R.D., LL.D., D.Sc., M.I.E.E., one of the early pioneers of Wireless Telegraphy, whose friendly assistance to Marchese Marconi when negotiating with, or carrying out tests for the Admiralty, commencing from the date of the inventor's arrival in this country in 1896 and continuing for many years thereafter, was of the greatest value to the progress of the art in those early days, and at the same time afforded one of the most pleasing aspects of the development of wireless in the British Navy in parallel with its world-wide development and application to maritime and commercial uses.

Sir Henry Jackson was born in 1855, and entered the Navy at an early age, reaching flag rank in 1906. He was appointed First Sea Lord in 1915 when Lord Fisher retired. In 1920 he became chairman of the Radio Research Board, and retired from the Navy in 1924.

He was an acknowledged authority in several branches of naval science, and of his many contributions to the learned societies perhaps the most outstanding on wireless subjects, although not the earliest, was that read before the Royal Society in 1902, entitled " On some Phenomena affecting the Transmission of Electric Waves over the Surface of Sea and Earth." He was a great experimentalist and a strong supporter of the amateur movement, and to a wide section of the wireless public his death will be felt as a personal loss.

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THE FIRST TRANSATLANTIC WIRELESS SIGNAL

THE MARCHESE MARCONI'S BROADCAST OF HIS EXPERIENCE

Thursday, December 12th, was the 28th anniversary of the historic wireless experiment conducted by Marchese Marconi between the Poldhu wireless station in Cornwall and St. Johns, Newfoundland, which resulted in the transmission and reception of the first wireless signal across the Atlantic Ocean.

This achievement, in December, 1901, only six years after Marchese Marconi's earliest experiments at his father's house in Bologna, Italy, definitely laid the foundations of world-wide wireless telegraph communication. The National Broadcasting Company of America marked the anniversary by special broadcast transmissions, and at its request Marchese Marconi broadcast from England, for re-transmission by means of the National Broadcasting Company's network of stations throughout the United States, a description of his experiences at St. Johns, Newfoundland, when he received the famous "S" signal, 28 years ago.

Marchese Marconi spoke from the British Broadcasting Corporation's studio at Savoy Hill, his speech being re-broadcast in the United States from the signals received from 5SW, the short wave experimental broadcasting station at the Marconi Works at Chelmsford.

MARCHESE MARCONI said: "It gives me very great pleasure to recount to Americans, through the courtesy of the National Broadcasting Company of America and the British Broadcasting Corporation, my experiences at the time when I first attempted—and, as it proved, successfully—to send Radio signals across the Atlantic Ocean, twenty-eight years ago, almost to the very hour.

"From the time of my earliest experiments I had always held the belief—almost amounting to an intuition—that radio signals would some day be regularly sent across the greatest distances on earth, and I felt convinced that Transatlantic Radio Telegraphy would be feasible.

"Very naturally I realised that my first endeavour must be directed to prove that an electric wave could be sent right across the Atlantic and detected on the other side.

"What was at that time a most powerful wireless station, was built at Poldhu, in England, for this purpose, and an antenna system was constructed, supported by a ring of 20 wooden masts, each about 200 ft. high.

"In the design and construction of the Poldhu Station, I was assisted by Sir Ambrose Fleming, Mr. R. N. Vyvyan and Mr. W. S. Entwistle.

"A similar station was erected at Cape Cod, in Massachusetts. By the end of August, 1901, the erection of the masts was nearly completed, when a terrific gale swept the English coasts, with the result that the masts were blown down, and the whole construction wrecked. I was naturally extremely disappointed at this unforeseen accident, and for some days had visions of my test having to be postponed for several months or longer, but eventually decided that it might be possible to make a preliminary trial with a simpler aerial attached to a stay stretched between two masts 170 feet high, and consisting of 60 almost vertical wires. By the time

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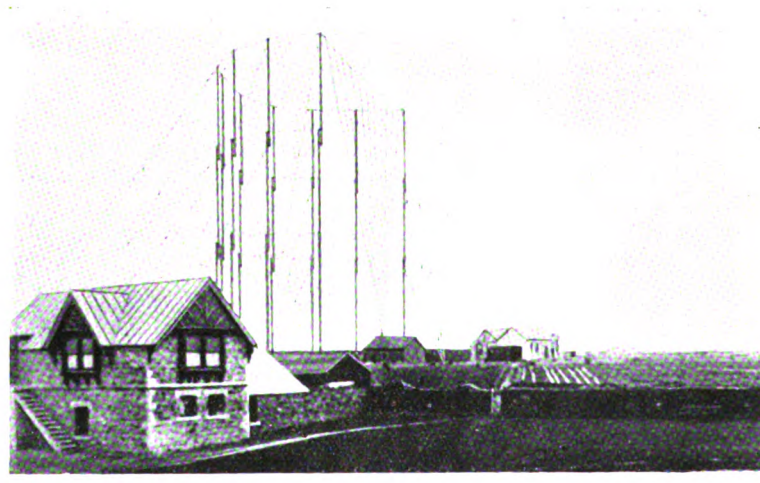
this aerial was erected, another unfortunate accident, also caused by a gale, occurred in America, destroying the antenna system of the Cape Cod Station.

Aerials Elevated by Balloons and Kites.

" I then decided, notwithstanding this further setback, to carry out experiments in Newfoundland, with a receiving aerial supported by a balloon or kite, as it was clearly impossible at that time of the year—owing to the wintry conditions, and the shortness of the time at our disposal—to erect high masts to support the receiving aerial.



Poldhu Wireless Station, December, 1901, *showing vertical aerial used for Transatlantic experiment.*

" On the 26th November, 1901, I sailed from Liverpool, accompanied by my two technical assistants, Mr. G. S. Kemp and Mr. P. W. Paget.

" We landed at St. Johns, Newfoundland, on Friday, December the 6th, and, before beginning operations, I visited the Governor, Sir Cavendish Boyle, and the Prime Minister, Sir Robert Bond, and other members of the Newfoundland Government, who promised me their heartiest co-operation in order to facilitate my work.

" After taking a look round at the various sites, I considered that the best one was to be found on Signal Hill, a lofty eminence overlooking the Harbour. On the top of this hill was a small plateau, which I thought suitable for flying either balloons or kites. On a crag of this plateau rose the Cabot Memorial Tower, and close to it was an old Military Barracks. It was in a room of this building that I set up my receiving apparatus in preparation for the great experiment.

" On Monday, December 9th, barely three days after my arrival, I and my assistants began work on Signal Hill. The weather was very bad and very cold. On the Tuesday we flew a kite with 600 feet of antenna wire as a preliminary test, and on the Wednesday we had inflated one of our small balloons, which made its first ascent during the morning. Owing, however, to the strength of the wind, the

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balloon soon broke away and disappeared in the mist. I then concluded that perhaps kites would answer better, and decided to use them for the crucial test.

Why the "S" Signal was chosen.

"I had arranged with my assistants in Cornwall to send a series of 'S's' at a pre-arranged speed, during certain hours of the day. I chose the letter 'S' because it was easy to transmit, and, with the very primitive apparatus used at Poldhu, I was afraid that the transmission of other Morse signals, which included dashes, might perhaps cause too much strain on it and break it down.

Preparing to fly a kite at Signal Hill, December 12th, 1901. Marchese Marconi is seen on the left.

"Mr. Entwistle, Mr. George and Mr. Taylor were in charge of the English Station at Poldhu during the transmission of signals to Newfoundland.

"On the morning of Thursday, the 12th of December, the critical moment for which I had been working for so long, at last arrived; and, in spite of the gale raging, we managed to fly a kite carrying an antenna wire some 400 feet long. I was at last on the point of putting the correctness of my belief to the test!

"Up till then I had nearly always used a receiving arrangement including a coherer, which recorded automatically, signals through a relay and a Morse instrument. I decided, in this instance, to use also a telephone connected to a self-restoring coherer—the human ear being far more sensitive than the recorder. Suddenly, at about half-past-twelve, a succession of three faint clicks on the telephone, corresponding to the three dots of the letter 'S,' sounded several times in my ear—beyond the possibility of a doubt!

"I asked my assistant Mr. Kemp for corroboration, if he had heard anything. He had in fact heard the same signals as I had. I then knew that I had been justified in my anticipations!

"The electric waves, which were being sent out into space from Poldhu had traversed the Atlantic unimpeded by the curvature of the earth—which so many considered to be a fatal obstacle—and they were now audible in my receiver in Newfoundland! Perhaps it will interest you if I now repeat the morse signal of the letter 'S' as I first heard it across the Atlantic 28 years ago.

[Marchese Marconi then transmitted the "S" signal by means of a key and an induction coil.]

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" I then felt for the first time, absolutely certain that the day when I should be able to send messages without wires or cables, across the Atlantic and across other oceans and perhaps Continents, was not far distant.

" The then enormous distance for radio of 1,700 miles had been successfully bridged.

" On the following day the signals were again heard, though not quite so distinctly. However, there was no further doubt possible but that the experiment had succeeded.

What the Experiment Proved.

" The result meant much more than the mere successful realisation of an experiment. It was a discovery which proved that, contrary to the general belief, radio signals could travel over such great distances as those separating Europe from America, and constituted, as Sir Oliver Lodge has stated, an epoch in history, besides being an astonishing and remarkable feat.

The kite elevated aerial at Signal Hill, Newfoundland, December, 1901.

" It must be remembered that at that time there was no suggestion of the existence of the Heaviside-Kennelly layer, nor of the reflection of electric waves from the higher regions of the atmosphere. The instruments we had at our disposal were very crude compared with those we have to-day. We had no valves or tubes, no amplifiers, no sensitive super heterodyne sets, no directional transmitters and receivers, and no means of making continuous waves. All we had for transmitting, was the means of making crude damped waves by means of irregular spark discharges. The receivers that were then employed were insensitive as compared with those of the present day.

" Following the success of my test, I was promptly notified by the Anglo-American Telegraph Company that as they had the exclusive right to construct and operate stations for telegraphic communication between Newfoundland and places outside that colony, the work upon which I was engaged was a violation of their rights.

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" I was asked to give an immediate undertaking not to proceed with my experiments and to remove my apparatus, or legal proceedings would be taken. I was absolutely astounded by this communication which, however, at least gave me the satisfaction of knowing that one of the great cable companies not only believed in my success but already feared the competition of radio transatlantic communication.

" I mention this to show why my experiments in Newfoundland were thus cut short. When, however, the reason became known, I received a very cordial invitation from the Government of Canada to erect a station in Nova Scotia—an offer which I gladly accepted.

Scientific Scepticism.

" The announcement that I had succeeded in transmitting radio signals across the Atlantic, was received with scepticism by most scientists—principally in Europe. The same thing cannot be said of American electrical engineers, for the American Institute of Electrical Engineers was the only technical and scientific body which first believed in me and my statement of having received signals across the Atlantic Ocean. It was the first distinguished and authoritative society enthusiastically to celebrate the event and to extend to me their generous support and valuable encouragement. They celebrated the occasion by a dinner given to me in New York, at which most distinguished American scientists took part, including men whose names were and still are, household words in electrical science, such as Dr. Alexander Graham Bell, the inventor of the telephone ; Professor Elihu Thompson ; Dr. Steinmetz ; Dr. Michael Pupin ; Mr. Frank Sprague and many others.

Marchese Marconi, with Mr. G. S. Kemp (left), and Mr. P. W. Paget, two of his earliest assistants, photographed at Marconi House on the 28th anniversary of the Newfoundland experiments.

" In less than three months from the date of the tests to Newfoundland these long distance results were more than confirmed by experiments carried out by myself on the s.s. Philadelphia of the American Line.

" The spanning of great distances is now child's play compared with what it was then. Beam projector, and other commercial radio telegraph and telephone

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stations are now exchanging daily hundreds of thousands of words between distant parts of the earth. Wireless telephony over world-wide distances is now a reality, together with transmission of pictures, and the day is approaching when television also will be a commonplace. It may even be that the transmission of power over moderate distances may be developed in the not far distant future. I must leave to your imaginations the uses which can be made of these new powers. They will probably be as wonderful as anything of which we have experience so far.

" I am glad to think that Mr. Kemp and Mr. Paget, who, as I have already told you were with me at St. John's 28 years ago, are with me at the microphone now, while I am addressing you, and I wish to send my most cordial greetings to all those interested in radio in America (I feel sure they form the majority of the American people), and to all my friends at the other side of the Atlantic."

Reception of the Broadcast in the United States.

Within a quarter of an hour of finishing the broadcast address Marchese Marconi received the first telegram of congratulation from the United States, and many others followed in quick succession.

The first telegram to be received was from an Italian listener in the Middle West, Mr. Francesco Occioni, who said the broadcast had been well received and enjoyed at his home in Denver, Colorado.

Mr. Merlin H. Aylesworth, President of the National Broadcasting Company of America, at whose request and through whose stations the Marchese Marconi's address was broadcast throughout the United States from New York to San Francisco, Seattle and Los Angeles on the Pacific Coast, telegraphed heartiest congratulations to the Marchese Marconi, and said the reception of the address was excellent, every word being understood. Mr. Aylesworth added that it had been broadcast throughout the whole of the United States over a network of fifty-nine broadcast stations.

Mr. David Sarnoff, Vice-President and General Manager of the Radio Corporation of America, telegraphed :—

> " American Scientists twenty-eight years ago were proud and glad to recognise your achievement. To-day they were thrilled to hear your personal description of this momentous event. Congratulations and my personal thanks."

American Scientific Tribute.

The American Institute of Electrical Engineers, to which the Marchese Marconi referred in his address as " the only technical and scientific body which first believed in me and my statement of having received signals across the Atlantic Ocean," telegraphed :—

> " Your statement to-day regarding recognition given your first transmission of radio signals across the Atlantic by this Institute is deeply appreciated. We are pleased to know that the 1902 dinner remains in your mind as a memorable occasion. Sincere congratulations upon your many important achievements in radio communication."

A group of radio " fans " sent the following message :—

> " Your radio talk to-day; reception fine, subject excellent, Glenwood Springs, the spa of the West, congratulates Great Britain and you."

These and many other telegrams from the United States, showed how great was the interest taken in America in Marchese Marconi's address.

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